Learning from Incidents in Airworthiness: A Novel Framework Tool for Safety Analysis

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Supervised by Dr Kyriakos I. Kourousis

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Abstract

Safe air travel is an expectation that we often invest little or no thought in. Fortunately, the industry has evolved to a stage where major air accidents are rare. Numerous lessons in aviation safety have unfortunately been paid for in the currency of human life. Many segments of the aviation industry support the idea that adverse and unwelcome events can be minimised through diligent reporting of incidents, event analysis and learning. The value of learning from incidents is not well supported in the implementing regulations. Therefore, little or no examination of learning inputs or outputs is required.

The intent of the study was to understand how various situations impact on learning from incidents in the continuing airworthiness management segment. To gain an empathetic understanding of the participants and their actions, an interpretative approach was adopted. An analysis of potential research methods and means of data collection was performed. Thirty-four semi-structured taped interviews were carried out. A qualitative analysis process based on Thematic Analysis employing a six- phase approach was used in support of the study.

The harvesting of information from incident reporting systems is a necessary input to continuously develop appropriate and effective training material. The inclusion of basic qualification criteria for human factor trainers in regulatory requirements should also be addressed. However, it is questionable if the perpetuation of these measures alone would support more effective delivery and application of lessons learned throughout the segment. One means of addressing this impending issue is to remodel regulatory, operational and training requirements to consider a new approach in the segment. Reflecting a combination of actions, events and conditions in a new basic model for human factor continuation training, may lay the foundations to better elucidate event causation and yield improved safety recommendations in the featured segment.

Authors Declaration

I hereby declare that the work contained in this thesis is my own and was completed under the supervision of Dr. Kyriakos I. Kourousis of the School of Engineering, University of Limerick. This work has not been submitted to any other university or higher education institution, or for any other academic award within this University.

Within this thesis there are four published articles:

Clare, J. and Kourousis, K.I. (2021), "Learning from incidents in aircraft maintenance and continuing airworthiness: regulation, practice and gaps", Aircraft Engineering and Aerospace Technology, Vol. 93 No. 2, pp. 338-346.
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Clare, J. and Kourousis, K.I., Learning from Incidents: A Qualitative Study in the Continuing Airworthiness Sector. Aerospace 2021, 8, 27.
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(The authors' contributions are certified in Appendix A)

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Dr Kyriakos I. Kourousis

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I dedicate this work to my late son Cormac (RIP) whose academic ability and humility continues to be an inspiration to me.

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List of Abbreviations

AD - Airworthiness Directive

ADREP - Aircraft/Incident Data Reporting

AMO - Aircraft Maintenance Organisation

ASRS - Aviation Safety Reporting System

CAMO - Continuing Airworthiness Management Organisation

Doc - Document

EASA - European Aviation Safety Agency

EC - European Commission

ECCAIRS - European Co-ordination Centre for Accident and Incident Reporting Systems

ED - Executive Decision

EU - European Union

FRAM - Functional Resonance Analysis Method

FAA - Federal Aviation Administration

FTA - Fault Tree Analysis

GM - Guidance Material

HF - Human Factors

IAA - Irish Aviation Authority

ICAO - International Civil Aviation Organisation

LFI - Learning from Incidents

MOR - Mandatory Occurrence Report (**VOR** - Voluntary Occurrence Report)

MTOW - Maximum Take-off Weight

PBP - Product Behaviour Process

SARP - Standard and Recommended Practice

SMS - Safety Management System

SIA - State Investigation Authority

SSP - State Safety Plan

STAMP - Systems Theoretic Accident Model and Process

STEP - Sequentially Timed Events Plotting

Chapter 1. Introduction

According to the 2019 'State of Global Aviation Document' (ICAO 2019) "*Improving the safety of the global air transport system is ICAO's guiding and most fundamental strategic objective*". An 11 per cent global increase in the number of accidents for the period 2017 to 2018 for commercial aviation operations is recounted. Additionally, the global accident rate increased from 2.4 accidents per million departures to 2.6 accidents per million departures (8 per cent increase on the 2017 rate). The long-term traffic forecasts in the (ICAO 2019) report suggest: "*global passenger traffic will almost double by 2032, reaching more than 6 billion passengers annually - compared to 3.5 billion in 2016 - and there will be more than 60 million flights*". In concert with this revelation, according to the Boeing Aircraft Company long-term forecast 2015-2034 (Boeing 2015), global economic expansion is expected to continue. As a result, the number of airplanes in service is expected to double over the next two decades.

1.1 Background

Many industries have identified that the drive to safely increase output in tandem with safety practices has been of assistance in raising awareness of associated risks, (Carroll and Fahlbruch 2011). Investments in safety generally advocate some guarantee for future profitability in an airline organisation. As the public demands more safety and at the same time as it demands more services at less cost, corporate shareholders will continue to expect higher returns, (Carroll and Fahlbruch 2011). However, the overall cost of an aircraft accident or serious incident is difficult to measure in addition to loss of life, reputational damage and in monetary terms. Most accidents and incidents are investigated under an international article which is enabled by a legal obligation placed on a member States within which an accident or (defined) incident occurs. States are required to institute and manage an inquiry in accordance with the guidelines as the laws permit. It is a fundamental International Civil Aviation Organisation (ICAO) requirement for all (aviation) design, production, operational and maintenance organisations to subscribe to an occurrence reporting system. For example, in Europe Commission Regulation (EU) No 1321/2014 (1321/2014) that relates to the aircraft maintenance code Part 145 requires entities and individuals involved in maintenance to consider and report defined occurrences to a number of parties. In parallel, flight crew and other professionals are also obliged under similar operational requirements to submit mandatory reports.

For EU regulated (1321/2014) maintenance and continuing airworthiness activities, the Part 145 maintenance reporting requirement is predominantly intended to highlight technical and design issues that affect or could affect aircraft safety. European member states mandate reporting of any issue that could result or has resulted in an unsafe condition that seriously hazards flight safety. Following a comprehensive review of the EU legislation that supports accident and incident investigation, Regulation (EU) No 376/2014 (376/2014) was developed. One of the main impetuses of this legislation was the recognition that expertise and regulatory framework requirements have had to evolve considerably over recent years. The directive also sets out to put greater emphasis on accident prevention by facilitating the holding of efficient and high-quality safety investigations. Some of the tasks and responsibilities associated with Regulation (EU) No 376/2014 (376/2014) are the brief of dedicated air accident investigation entities and competent authorities. Member state occurrence reporting obligations appoint notarised aviation entities such as an aviation authorities to oversee the establishment "*of an occurrence reporting system as part of the management system…..in order to contribute to the aim of continuous improvement of safety*" (2018/1139).

1.2 Research Objectives

Aviation safety is hugely reliant on well-executed maintenance and competent management of the functions. In comparison to other inputs to aircraft operations, under performance relating to maintenance intervention may often be difficult to detect. There can be latent issues remaining undiscovered for some time until the necessary conditions arise for an undesirable event to occur. In addition to mandating the defining, recording, collating, a more agile framework for the sharing of events could yield a richer source of information in support of learning from incidents (LFI) syllabi. This research undertook a qualitative examination of staff involved aircraft maintenance and continuing airworthiness activities in order to identify factors that could support further learning from incidents within this industry sector. To achieve this, it was necessary to address the following objectives:

O1. To review current literature on learning from incidents in order to identify factors that relate to learning from incidents.

O2. To interview a sample of professionals working in the sector about reporting incidents and how learning from incidents is achieved in their organisations.

O3. To identify obstacles to learning and translate these into recommendations capable of setting a solid foundation for an improved appreciation of the benefits of learning from incidents.

1.3 Research Questions

To progress the objectives of the research, it was necessary to address the following questions:

RQ1. What local mechanisms enable learning from incidents in an operational environment?

RQ2. What obstacles to learning from incidents are experienced?

RQ3. Why do obstacles to learning from incidents exist?

The literature review illuminated a pressing need to address a body of work that remains to be performed within the segment under focus. The obligatory relationship between the expectation to potently learn from incidents and what is inferred in procedural form is not sufficiently appointed in domain requirements. This inherent deficiency may be a causal factor that has propagated a paradigm that undervalues the utility and capability of learning from incidents. Moreover, it may also be responsible for the light-touch approach to defining a regulatory architecture capable of empowering improvements in key learning participant competence requirements, defining a standard approach to causation and proffering a model that supports a standard learning product centric archetype.

The thesis aims to offer a context for the four published academic journals. In addition to the Introduction chapter, the document comprises of five other chapters. An outline of the work performed within each subsequent chapter is described below and the relationships between research questions are reflected in figure 1.1.

Chapter 2 details a systematic literature review performed in support of the research. The key purpose and motivations for the body of work are explained in the instalment. The research is of particular interest since systematic literature reviews are scarce in this aviation segment. The work provides evidence of impediments to learning from incidents (LFI) not only in parallel domains but also in aviation particularly, lack of effective focus on establishing appropriate event causation.

Chapter 3 delineates the interfaces that enable a view of regulatory requirements that stakeholders must address in support of LFI. The chapter identifies regulatory gaps that if addressed could validate a more effective approach to LFI withing the segment under focus.

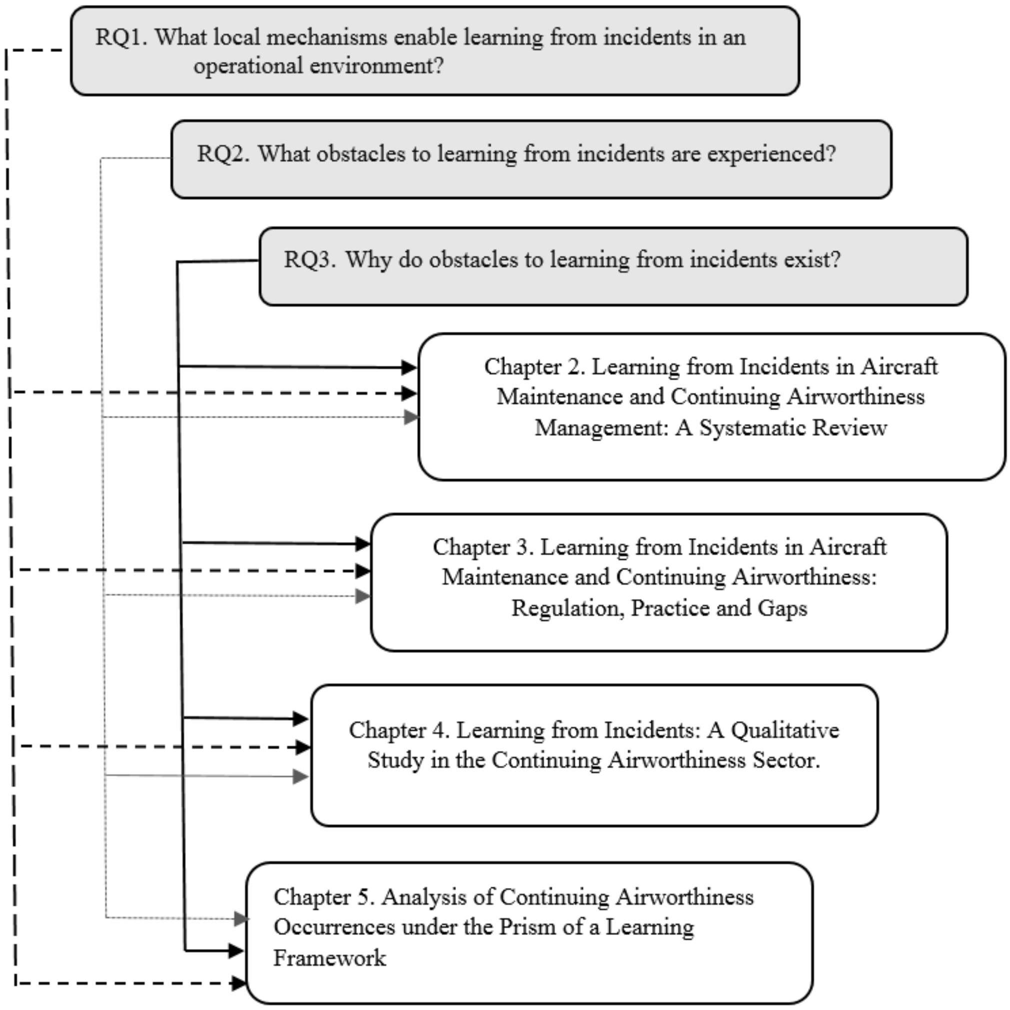

Figure 1.1. Map of inter-relationship between research questions and chapters.

Chapter 4 progresses on the earlier chapters and provides further details of the qualitative study. Recognising one of the main aims of the research was to elucidate factors that enable LFI, the study reveals the benefits of just culture and formal recurrent training programmes in this respect. Limitations such as those aligned with poorly designed training syllabi and lack of mandatory requirements for key persons involved in training are highlighted as impeding factors. The chapter concludes with an overview of the framework applied to the study and the architecture of the study results.

Chapter 5 documents the learning potential a sample of incidents relating to Irish registered aircraft displayed. These events were drawn from an industry central repository database. A new incident learning archetype is introduced and suggestions how reported incidents can be successfully translated into learning and preventing recurrence are considered.

Chapter 6 summarises the key achievements and also transverses the potential for the application of the research and possible future work execution opportunities.

1.4 Overview of Methodology

Interpretive research seeks to develop a richer understanding of the complex world of lived experience from the point of view of those who live in it. This goal is variously spoken of as an abiding concern for the life world, for the emic point of view, for understanding meaning, for grasping the actor's definition of a situation, for verstehen. (Schwandt, 1994, p.118)

The intent of this study is therefore to examine how various situations impact on learning from incidents in the aircraft maintenance and continuing airworthiness management domain. Thus, in order to gain an empathetic understanding of the participants and their actions, pursuit of '*verstehen*' considers adopting an interpretive paragon as an approach. This viewpoint is also shared by scholars such as Walsham (1995) and Lee (1999) who consider this approach as appropriate when elements of human behaviour are being examined.

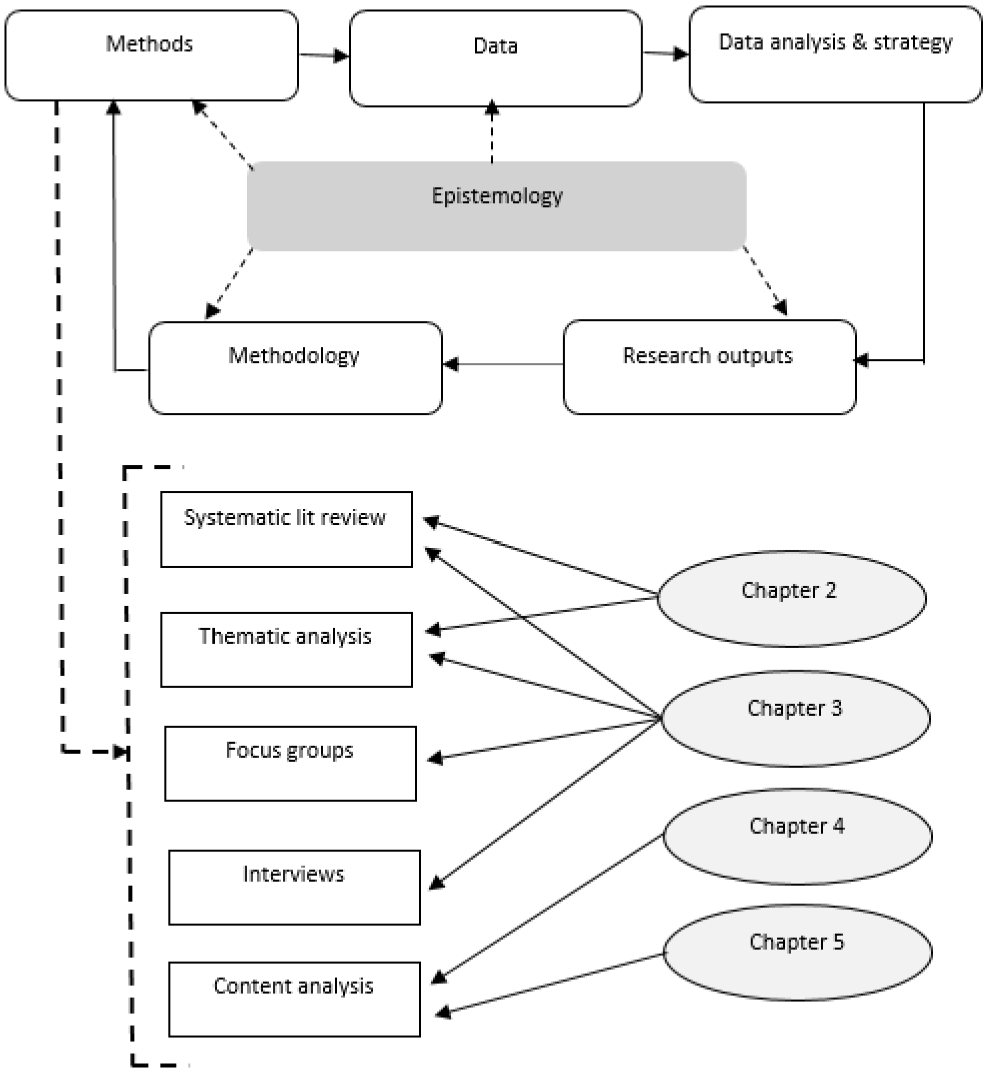

Figure 1.2. Overview of Methodology and relationships with chapters.

Although many of the existing studies that illuminate behavioural and cultural aspects of organisations contribute greatly to the repository of knowledge, qualitative methodologies are popular in research areas. e.g. Myers *et al.* (2010) and Baxter and Eyles (1997). Crossler *et al.* (2013) suggest an expansion of studies that enlist qualitative techniques as a means of overcoming methodological challenges often associated with quantitative research. "*Qualitative studies are not normally generally aiming to make statistically based generalizations through the application of formal comparable techniques*" (Hart 2005). The research project employed a qualitative research methodology to generate 'rich' findings in support of gaining a good understanding of the learning environment in the featured domain. According to Maykut and Morehouse (1994), the purpose of qualitative research is to discover the inner world of perceptions and meaning-making in order to gain an understanding, to describe and explain certain social phenomenon from participants' perspectives.

One of the first steps in the research phase (figure 1.2) was to make application to and receive Faculty of Science and Engineering Research Ethics Committee approval from the University of Limerick. As the unit of analysis was the individual, it was decided data would be collected with the assistance of a semi-structured template. Developing the template was assisted by the outputs of a systematic literature review (Okoli and Schabram 2010) that was performed concurrently with focus group (Kitzinger 1994) activity. The outputs from these activities informed the semi-structured template and also formed part of the architecture for the thematic analysis (Braun and Clarke 2006). Data arising from the systematic literature review was analysed with the assistance of thematic analysis (Braun and Clarke 2006) also. A content analysis (Weber 1990, Okoli and Schabram 2010) of pertinent regulatory material was also performed.

In summary, the research undertook a qualitative examination of staff involved in aircraft maintenance and continuing airworthiness operations in order to identify factors impeding and augmenting learning from incidents within this industry sector. In order to gain an empathetic understanding of the participants' experiences of these conditions, an interpretative paragon was adopted. In combination with the data arising from the study and the outputs from a systematic literature review, four published academic papers arose.

Preamble and Statement of Author's Contribution Chapter 2

The following chapter documents and presents the results of a systematic literature review performed within the parameters of defined search criteria. The publication reveals enablers and constraints to learning from incidents and could be used in support of reform to the associated domain regulatory codes.

Author Contributions: Conceptualization, J.C. and K.I.K.; methodology, J.C.; formal analysis, J.C.; investigation, J.C.; validation, J.C and K.I.K.; data curation, J.C.; writing—original draft preparation, J.C. and K.I.K.; writing—review and editing, J.C. and K.I.K. All authors have read and agreed to the published version of the manuscript.

Chapter 2. Learning from Incidents in Aircraft Maintenance and Continuing Airworthiness Management: A Systematic Review

Abstract.

The purpose of this systematic review is to highlight the salient elements of learning from incidents in the aircraft maintenance and continuing airworthiness management area. This involved the review of more than 1,000 publications reflecting practice in different domains. The cache was eventually distilled to 18 publications of relevance to learning from incidents. The systematic review of the literature was not intended to be exhaustive, but it was deliberately bound by the parameters of predefined search terms. A robust analysis was performed on the 18 distilled publications with the use of the NVivo software. A critical and systematic examination of this body of literature further supported the development of the five codification themes. The analysis of the literature revealed the benefits of a just culture as an enabler of reporting and learning from incidents. Moreover, it identified limitations inherent in the current body of knowledge. The most evident being a paucity of literature relevant to the featured industry segment. Some impediments to learning from incidents are also highlighted. Central to this is the prevalence of lack of effective focus and practice on satisfactory causation of events. Currently the efforts applied across many featured domains appear to be based upon ineffective legacy linear practices. However, emerging investigative philosophies that look beyond direct cause and effect contain opportunities for practitioners to consider causation through dawning axioms. This systematic review could be used in the European aviation regulatory activities associated with improving learning from incident in aircraft maintenance and continuing airworthiness management.

2.1 Introduction

Freeman Dyson, the notable theoretical physicist and mathematician, once said, "*Aviation is a branch of engineering that is least forgiving of mistakes*" (Redding *et al.* 2017). It is true that such high reliability domains can pose a great degree of risk that may in turn contribute to mistakes being made. However, a guiding principle of continuously improving aviation safety is our ability to learn from events such as incidents. In the world of aviation safety, standards and recommended practices tend to be biased towards translating the experiences from such events into tangible outcomes aimed at preventing similar re-occurrences.

A review of safety in aviation from the perspective of maintenance and continuing airworthiness management staff is key to understanding the relationship between safety and the concept of learning from incidents (Lukic *et al.* 2012). Despite the efforts of fallible humans and the ever-increasing complex systems they moderate, achieving a utopian reality where there are no risks or hazards present is clearly an unreasonable expectation (Perrow 1999). Safety in aviation has evolved along a continuum from the early 1900's where aircraft mechanical and design issues were the primary contributors to aircraft accidents, according to the International Civil Aviation Organisation (ICAO) (ICAO 2013b). Improvements in these technical factors reached a plateau in the 1970's and the challenges realised then were centred around human performance and limitations (Transport Canada 2003). Notwithstanding efforts and investment in human factor initiatives, accidents and incidents continued to occur. In the 1990's there was a clear recognition that as the aviation industry continued to develop, there were a number of factors outside the human at play with a potential to affect safety behaviour (Hobbs 2001). This paradigm-shift informed today's systematic approach to safety, and in particular the approach to learning from incidents (Leveson 2011).

Most people relate safety to freedom from risk and danger (Reason 1997). Unfortunately, risk and danger are often ubiquitous in the presence of high reliability activities. Managing sources of risk and danger are a tall order for some organisations. The ICAO Doc 9859 (ICAO 2013b) recognises that "*aviation systems cannot be completely free of hazards and associated risks*". However, the guidance does acknowledge that as long as the appropriate measures are in place to control these risks, a satisfactory balance between "production and protection" can be achieved. Perrow (1999) acknowledges that "*we load* *our complex systems with safety devices in the form of buffers, redundancies, circuit breakers, alarms, bells, and whistles*" because no system is perfect.

When one thinks of the word 'incident', it conjures up the notion of an action that may have grave consequences. Similarly, the word 'accident' is often used in the context of an unplanned event or a particular circumstance. In many industrial sectors and business domains, these descriptors are used with a degree of interchangeability when the words are applied to describe events. In the world of aviation, there are clear high-level definitions for both event categories, and these are based on potential for harm. Throughout aviation, learning from incidents is often considered to be one means of augmenting what Perrow (1999) terms "*safety devices*". "*Experience is the best teacher*" according to Kleiner and Roth (1997) as they claim that the causes of the mistakes are often not featured and continue to be present in the absence of learning. In general terms, Nonaka (1991) suggests that creating new knowledge extends past a mechanistic approach and is strongly related to employees' insights. An effective enabler of learning in this area is the collation of information on incidents. Details of the related processes, environment, procedures, competencies and implementing timely corrective actions all have a positive impact on learning and help prevent recurrence in the future. Learning from incidents is therefore mainly associated with post incident learning.

Detecting and identifying hazards highlighted through incident reporting systems is recommended by International Civil Aviation Organisation (ICAO) standards and recommended practices as an effective means of achieving practicable levels of safe operations. Therefore, objective data mined from a reporting system offers the potential to enlighten aviation stakeholders and to illuminate weakness that may be present. Such information can assist with a better understanding of events and augment mitigating measures against the potential effects of these hazards. When incidents occur, this can be an indication of a failure in an organisation's process and/or practice. Due to continuous challenges faced by the organisations in the aviation industry there is potential to learn from resulting incidents and pre-cursors. The learning is based on the potential new knowledge available from the associated collection, analysis, and interventions of these events. Effective learning can be considered as a successful translation of safety information into knowledge that actively improves the operating environment and helps prevent recurrence of events we can potentially learn from. Learning in this context can often be experienced as modifying or implementing new knowledge where cultural, technical or procedural elements are integrated. Therefore, when learning in this context is transformed into measures to prevent re-occurrence, an organisation often has a reasonable means of mitigating future similar events.

The objective of this systematic review is to examine how learning from incidents occurs in aircraft maintenance and continuing airworthiness management and other sectors and what issues impact learning in those areas. It also intends to identify the contributing and constraining factors to learning from incidents. A qualitative review approach was selected as it has the advantage of providing a deeper contextual understanding of the literature and can assist with better research integration. Applying a degree of rigour and comprehensiveness can assist with advancing knowledge and identifying research gaps and aspects for further research in this particular area.

The publication's systematic literature review covered primary publications up until 2017. As the subject of learning from incidents is a valid topic with potential to augment safety, a brief review of a cross-section of the latest publications was performed to see if a 'delta' in the knowledge exists. Insley and Turkoglu (2020) reaffirm aircraft maintenance is still a key point of concern within many areas of aviation. Their work highlights frequently recorded maintenance related consequences, naming runway excursions and air turn-backs in the highest percentile. The study identified factors relating directly to these events naming inadequate and incorrect procedures, poorly executed inspection tasks and incorrect installation as common causal factors ascribed to the event categories named. These issues are not unique to Europe. Habib and Turkoglu (2020) review a dataset of maintenance related incidents originating outside of Europe (Nigeria). Their analysis revealed causal factors such as poor aircraft husbandry, deficiencies in inspection and testing and inadequate safety oversight (organisation & regulator). Habib and Turkoglu (2020) also consider the consequential impact of errors as causal elements in subsequent events. They also highlight the increase in incidents recorded and attribute this to a recent increase in air movements. Batuwangala *et al.* (2018) present the idea that forecasted growth in air traffic requires a strong effort to ensure aviation incidents continue to be progressively reduced. They recognise a novel approach to safety improvements will need to be propagated in support of this. Although the authors point out some of the benefits of implementing a safety management system (SMS), they reaffirm the notion that not all areas of aviation operations are mandated to comply with SMS requirements. Some of the implementing constraints recorded by

Batuwangala *et al.* (2018) include, protection of safety data/reporters, lack of just culture & reporting and reporting system deficiencies to name a few.

The review of the sample examining a cross-section of current research in the area of aircraft maintenance and continuing airworthiness does not identify any significant new knowledge in support of this publication. The additional exercise re-affirms the concept that some organisations are continuing to ineffectively embrace a desire to learn from incidents.

2.2 Material and Methods

In order to conduct an efficient and effective review, a structured approach was deemed necessary. Okoli and Schabram (2010) state that "*a dedicated methodological approach is necessary in any kind of literature review*". An initial search of literature highlighted a scarcity of best-practice guidelines for conducting systematic literature reviews in the subject domain. This situation is also experienced in other sectors as Levy and Ellis (2006) and Webster and Watson (2002) confirm. Qualitative research involves handling considerable volumes of data and a degree of discipline is required so that search results, decisions regarding subject inclusions & exclusions are recorded and references are well managed.

Endnote was used in support of the literature review during this research. An electronic database is useful for supporting a search strategy, arranging publications and storing references (Houghton *et al.* 2017). The qualitative data analysis software NVivo (NVivo 2020) was used to augment the data management, storage and analysis associated with the literature review. NVivo possesses many functions that are capable of facilitating the synthesis of a review (Bandara *et al.* 2015). However, the software does not have the capability of understanding text and the analytical skills of a researcher cannot be replaced in this respect.

The outcome of a qualitative research initiative are contextual findings as opposed to broad generalisations. Maykut and Morehouse (1994) (p.18) state that, "*words are the way that most people come to understand their situations; we explain ourselves with words; we defend and hide ourselves with words*". Qualitative researchers seek out patterns in the words of participants' transcripts. This study endeavoured to gain access to the realm of the study participants and their perceptions of the subject of learning from incidents. This also provided a rationale in support of adopting a qualitative technique.

The suitability of a qualitative methodology has been based on its capability to enable the following elements:

- Capable of generating rich findings.
- Possibility to understand participant attitudes.
- A novel approach to the study of learning from incidents within the featured segment.
- Ability to support researcher insights into the area of focus.
- Allows the researcher to maintain an open outlook.
- Offers a degree of flexibility to the researcher.
- Cost effective means of collecting data.

In summary, qualitative research is based on a phenomenological locale. It is an encompassing approach that accounts for context within which human experiences arise and gleans learning from particular cases or events. Qualitative research attempts to gain access to the inner world of perception and to understand and explain the social process from the perspectives of the participants. In this situation, the approach is not initiated with the aid of a hypothesis intended for testing but rather using a focus that traverses the researcher to a point of discovery supported with an inductive modus operandi. However, this decision is not intended to undermine the effectiveness of quantitative techniques within this area of interest. The study is unwavering in its support for the view that (individual and combined) qualitative and quantitative approaches possess equal value in terms of their investigative potential in this area of focus.

2.2.1 Search with Predefined Terms

Bandara *et al.* (2015) suggest two main criteria to consider before a search to identify papers for extraction and review begins: the source and search strategy. The source considers which outlets and databases to target and the search strategy refers to the search terms and discipline to be exercised during the manuscript extraction process. A systematic search of the literature was performed in the following databases:

- Web of Science (Web of Science 2020)
- Scopus (Scopus 2020)
- IEEE Xplore (IEEE Xplore 2020)
- ProQuest (ProQuest 2020)
- EBSCO (EBSCO 2020)

The following set of predefined terms associated with the thematic of the systematic review was selected to search in these sources.

- ‘learning from incidents’
- ‘learning from experience’
- ‘aircraft maintenance’
- ‘aircraft management’
- ‘safety management systems’

This step concluded with the creation of an initial set of publications, which would further be filtered in next steps.

2.2.2 Practical Screen of Title and Abstract

In this step, each title and abstract were reviewed (practical screen). This part of the process had to be broad enough to create a sufficient number of applicable publications but also had to be practically manageable. The following criteria were laid down for the practical screen of the source bibliographic details, title and abstract:

- Subject - Related to learning from incidents and past experiences
- Setting – Any high reliability industry or sector where learning from incidents is critical.
- Publication – Journal or peer reviewed conference proceedings
- Date range – published post 1992

The output of the practical screen step produces a list of publications denoted as the screened set of publications. An Endnote library was created to store and manage the full text of the retrieved publications.

2.2.3 Classification to Primary and Secondary Publications

This step involved the filtering (classification) of publications in the following two categories:

- Primary publications - any research publication based on original data collected by the publications’ author(s)
- Secondary publications - those publications based on data generated by somebody other than the author(s), e.g. a review and use of existing literature/data developed by another party.

Effectively, the screened set of publications was split over to a subset of primary publications and subset of secondary publications. Of those, in the next step, only the subset of primary publications was used.

2.2.4 Application of Inclusion and Exclusion Criteria

Brunton *et al.* (2012) suggests there needs to be explicit inclusion and exclusion criteria in order for the reviewer to screen titles and abstracts for topical, population, temporal and methodological relevance. Having a set of criteria helps to reduce any researcher bias in the screening system. A set of inclusion and exclusion criteria was developed considering the below objectives and in accordance with the guidelines included in (Meline 2006) and (Wienen *et al*. 2017):

- To review current literature to identify factors relate to learning from incidents
- To identify obstacles to learning from incidents
- To make recommendations how learning from incidents might be improved in the aircraft maintenance and continuing airworthiness management sector

In this context, the inclusion and exclusion criteria presented in Table 2.1 were used for the filtering of the subset of primary publications. The output of this step leads to the creation of the final set of publications.

Table 2.1. Inclusion and exclusion criteria used for the filtering of the subset of primary publications [table adopted from Clare and Kourousis (2021)]

Included	Excluded
Research studies	Literature reviews
Qualitative and mixed methods	Quantitative methods
Perceptions and experiences	Focused on decision-making and legislative requirements
Reference to just culture	
High reliability settings	
Published post 1992	
Peer reviewed publications	
Industry based settings	
Original studies	

2.2.5 NVivo Analysis and Codification with Themes

In this step, the Endnote library containing the final set of publications is imported to NVivo for further analysis. The following approaches, previously suggested by Bandara *et al.* (2015), were used for the selection of the codification themes:

- Deductive – themes reported on are predetermined to some extent. In this case, these predetermined themes were the output of a focus group process. The present review paper does not report details on the focus group, as this is within the scope of a future research paper of the authors.
- Inductive – themes reported are derived from analysis of the literature

In addition to the three inductive themes (learning from incidents, just culture, pre-cursors) arising during the literature review, two additional themes (root cause, reporting) were deduced from conducting focus group activities concurrently with the review. The aggregate of both of these efforts resulted in five themes being developed. According to Kitzinger (1994), "*focus groups are group discussions organised to explore a specific set of issues such as people's views and experiences…*". The idea of conducting group interviews is not a new one. Bogardus (1926) is an early example of a reference to utilizing the group interview. Frey and Fontana (1991) say that group interviews can be formally structured for a specific purpose or can be performed in a more informal setting where a researcher can "*stimulate a group discussion*". A total framework of five nodes eventually representing the themes was constructed in the NVivo database and used in support of completing the systematic literature review. These five nodes were also later used as the main framework for the semi-structured interview template. The description and origin (focus group or literature analysis) of the themes identified are described in Table 2.2.

Table 2.2. Codification themes used in the NVivo analysis of the final set of publications.

Codification Theme	Description	Origin
Root Cause	Reason to establish causation	Focus Group
Reporting	Value of reporting to learning from incidents	Focus Group
Learning from Incidents	Outcomes of learning from incidents	Literature Analysis
Just culture	Impact of just culture on learning from incidents	Literature Analysis
Precursors	Contribution of precursors to learning from incidents	Literature Analysis

Using the codification themes, the final set of publication was searched using the NVivo software to extract and code the passages identified to any of the coding categories. NVivo only provides thematic classifications of data based on the occurrence of key words. This merely assisted in identifying common prescribed keywords in publications, enabling classification into categories or clusters of words and examination of relationships within these publications. As NVivo does not perform analysis, the researcher must search the outputs and extract meaning for themselves. Thus, each of the publications were physically reviewed inductively by the researchers. Effectively, the final set of publications was searched and coded to the Table 2.2 which has five themes. The coding process consisted of selecting relevant passages of text that were captured in one or several of the framework nodes. The overall document screening process and associated steps described in the previous subsections are illustrated in the flowchart of Figure 2.1.

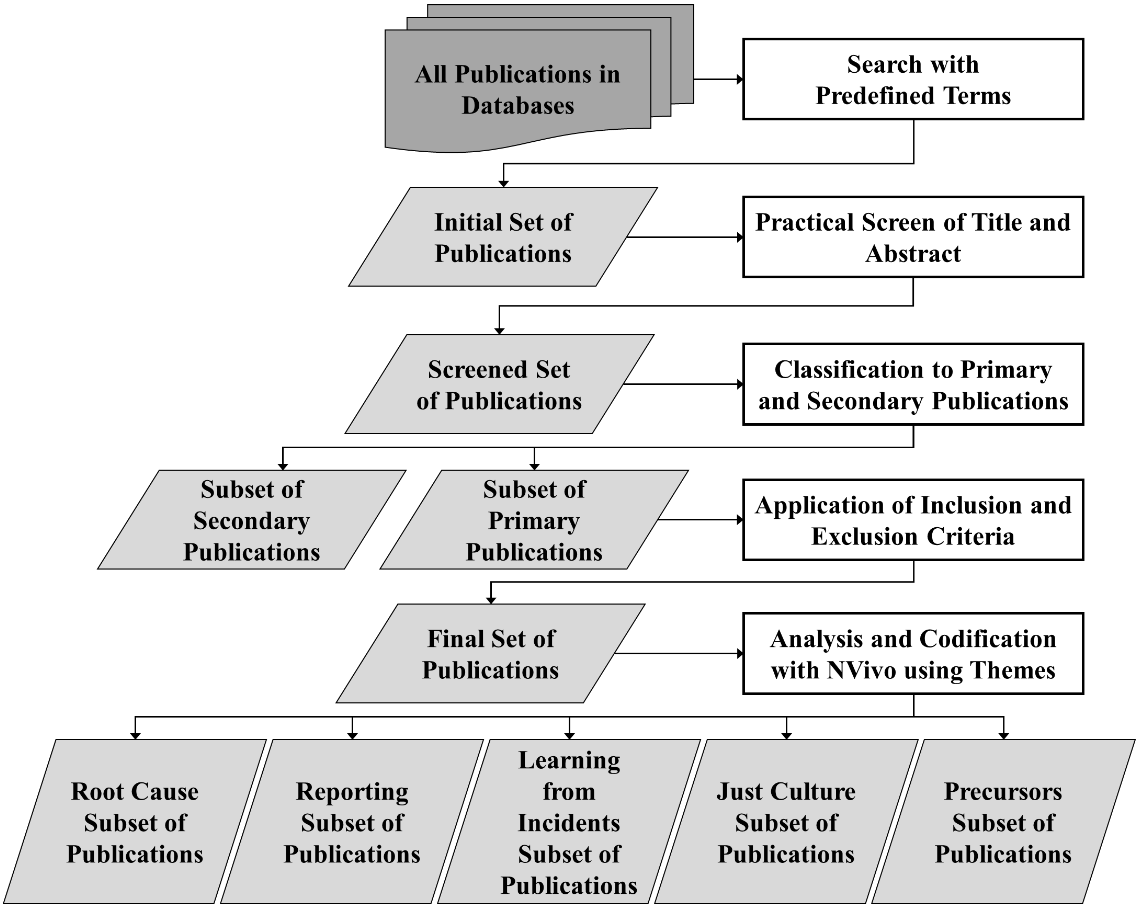

Figure. 2.1. Flowchart of the overall document screening process and associated steps utilised in the systematic review.

Maykut and Morehouse (1994) define a propositional statement as "a statement of fact the researcher tentatively proposes, based on the data." Memos were used to draft these summary statements which form part of Section 3 of this paper.

2.3 Results and Discussion

In the first step of the process described in the Materials and Methods section of this paper, the search with predefined returned in excess of 1,000 publications (initial set of publications). From this tranche, a total of 239 publications were retrieved in the practical screen phase (constituting the screen set of publications), which were then classified to a subset of 53 primary publications and a subset of 186 secondary publications. The final set of publications was derived by applying the inclusion and exclusion criteria of Table 2.1, leading to a total of 18 publications. The progressive filtering process is presented in the flowchart of Figure 2.2.

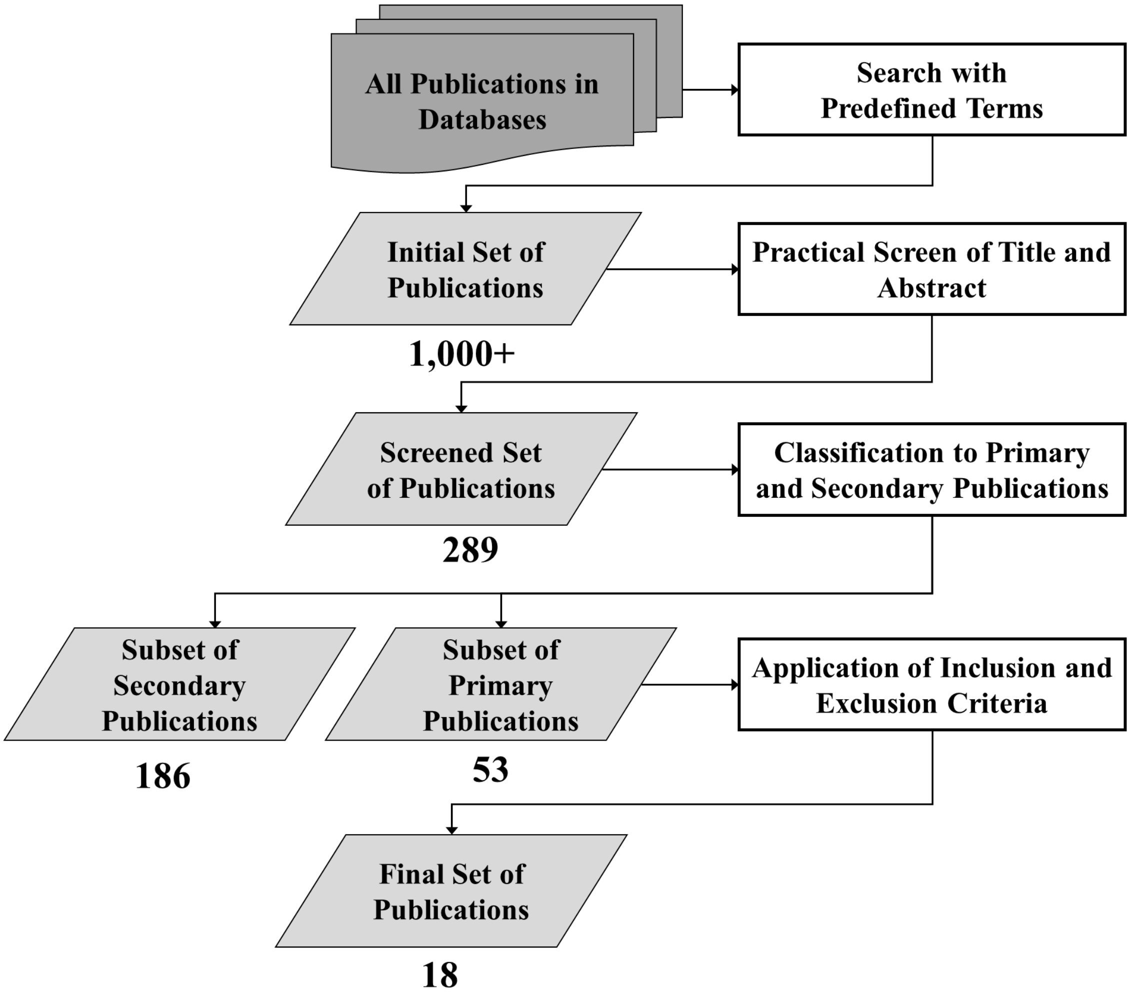

Figure. 2.2. Output of the progressing filtering process applied during the systematic review, leading to the 18 publications (final set of publications).

The 18 publications are summarised in Table 2.3, where the utilised methodology (qualitative, quantitative of mixed) and the application domain (different industries) are also provided.

Table 2.3. A summary of attributes of the papers arising from the systematic literature search.

Paper	Methodology	Domain
Atak and Kingma (2011)	Qualitative	Aircraft maintenance
Drupsteen and Hasle (2014)	Qualitative	Chemical, construction, manufacturing
Drupsteen and Wybo (2015)	Qualitative	Healthcare
Drupsteen et al (2013)	Qualitative	Chemical, construction, energy, government, metal, transportation.
Furniss et al (2016)	Qualitative	Technology, transport, energy production and healthcare
Gartmeier et al (2017)	Qualitative	Healthcare
Gerede (2015)	Qualitative	Aircraft maintenance/regulatory
Gray and Williams (2011)	Qualitative	Healthcare
Hall-Andersen and Broberg (2014)	Qualitative	Engineering consultancy
Hobbs and Williamson (2002)	Mixed	Aircraft maintenance
Jacobsson et al (2012)	Mixed	Petrochemical, food & drug, energy
Lukic et al (2012)	Qualitative	Energy
Pickthall (2014)	Mixed	Aircraft maintenance
Silva et al (2017)	Mixed	Manufacturing, construction, production, and distribution of energy
Steiner (1998)	Qualitative	Production and distribution
Storseth and Tinmannsvik (2012)	Qualitative	Railway and maritime
Ward et al (2010)	Qualitative	Aircraft maintenance
Zwetsloot et al (2017)	Mixed	Manufacturing, construction, other

In the next step, this (final set) of 18 publications was analysed and codified with NVivo, using the five codification themes described in Table 2.2. This has led to the distribution of publications per codification theme shown in the flowchart of Figure 2.3.

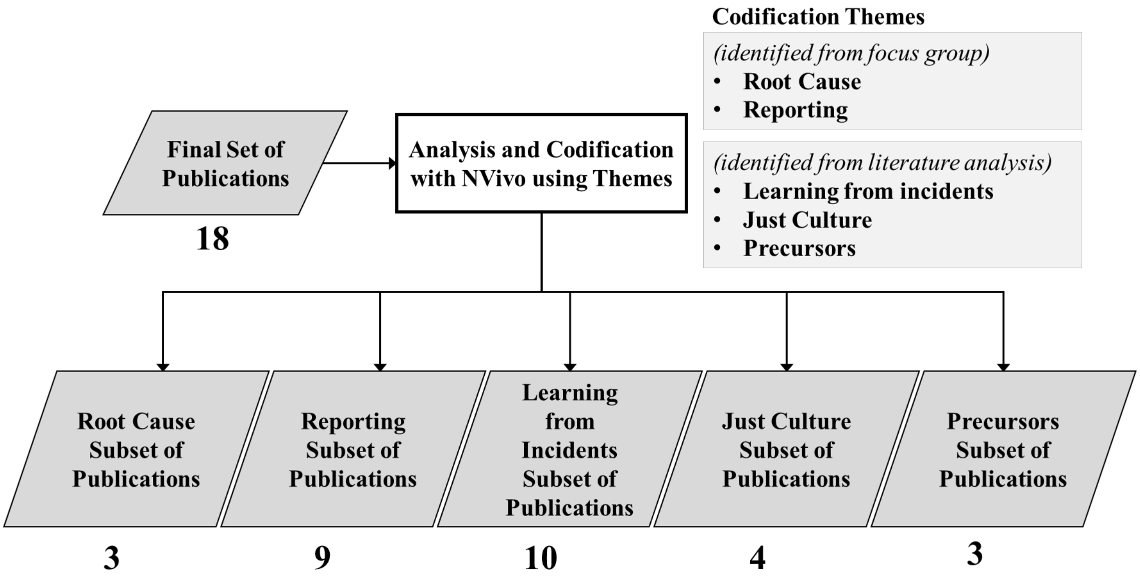

Figure. 2.3. Distribution of the final set of (18) publications in the five codification themes following the NVivo analysis and codification step of the systematic review process.

One can observe from this distribution that publications share some common codification themes. This is presented in Table 2.5, which provides the results of the mapping exercise of the 18 publication against each of the five codification themes.

Table 2.4. Mapping of 18 publications (final set of publications) against the five codification themes.

	Precursors	**Just Culture**	**Root Cause**	**Reporting**	**Learning from Incidents**
	3	**4**	**3**	**9**	**10**
Atak and Kingma (2011)				X	
Drupsteen and Hasle 2014		X			X
Drupsteen and Wybo (2015)	X				X
Drupsteen et al (2013)					X
Furniss et al (2016)					X
Gartmeier et al (2017)				X	
Gerede (2015)		X			X
Gray and Williams (2011)				X	
Hall-Andersen and Broberg (2014)				X	
Hobbs and Williamson (2002)	X		X	X	
Jacobsson et al (2012)			X		X
Lukic et al (2012)					X
Pickthall (2014)			X	X	
Silva et al (2017)		X			X
Steiner (1998)				X	
Storseth and Tinmannsvik (2012)				X	
Ward et al (2010)	X	X			X
Zwetsloot et al (2017)				X	

Memos were used to draft the literature summary statements, which formed the final narrative for the synthesis. NVivo facilitated collation of the summary statements and enabled a transparent audit trail in support of the literature review exercise presented separately in sections under the five codification themes.

2.3.1 Root Cause

An overview of the Jacobsson *et al.* (2012) study findings that relate to poor causation identification can be consolidated as follows: fewer event aspects recorded, often only operator error and technical failure recorded and shallow root causation. It was found that when limited analysis of underlying event causes is performed, only limited effective actions are possible. This is evident when poor root cause analysis only contributes to minor procedural and cosmetic changes are aimed at preventing recurrence. Such deficiencies were considered to have a limited impact upon the potential lessons available as a result of ineffective root cause establishment.

Pickthall (2014) considers root cause through the lens of an individual's competence when a technical and human factors-related impediment is present. The research examined the prevalence of these factors when aircraft maintenance staff perform fault diagnosis on complex aircraft systems. The researcher found that often maintenance staffs are unable to diagnose faults in an accurate and timely manner. The results of the study indicated that events are often caused by poorly resourced supports, such as system diagnostics and test equipment. On a practical level, these contributing factors are believed to have a negatively influence on the inability to establish adequate root causes and prevent the recurrence of faults.

The Hobbs and Williamson (2002) research study explored patterns of potentially unsafe acts often perpetuated by aircraft maintenance staff. Violations (routine & exceptional) and mistakes were found to be closely related to deteriorating maintenance standards. A potential relationship reinforces a link between violations and less than optimal safety standards. According to the researchers, root cause of such violations can often be traced back to the prevailing culture within the organisation itself.

2.3.2 Reporting

In their work, Gray and Williams (2011) examined whether culture surrounding learning from incidents can be compounded by "*strategic defence routines*", resulting in recurrence of the event or similar ones. Their study was conducted through questionnaire in health services' domains. They found that real learning from incidents can take place as a result of a transformation effort facilitated by a holistic approach. The authors refer to "*re-framed learning approach*", however, the publication contains little practical exemplars which would expand more on the details and the applicability of a similar approach to learning from incidents.

Gartmeier *et al.* (2017) examined if reporting can be used as a strategy for workplace learning in a health service setting. They have considered error reporting attitudes and behaviours in a two-stage study performed via a longitudinal survey. The results suggest that organisations should highlight benefits of error reporting, ease of use and the accessibility of reporting systems is important, barriers can be modified to encourage reporting.

Bjerg Hall-Andersen and Broberg (2014) conducted a "*natural experiment*" in an engineering consultancy firm. Following implementation of an information transfer database, discreet learning processes found to be interconnected within some domain elements. However, there is no evidence of collective interdomain learning across functions. The lessons learned are not through potential negative consequences and respective actions arising from a reporting system input but brokered through a moderated database. A single "*embedded*" case study may not support the generalizability of the results in other domains. However, for those who wish to develop a better understanding of learning processes across knowledge boundaries, the "*implications for practitioners*" contained in the study are considered applicable.

Steiner (1998) conducted a qualitative study set in a workshop environment with data collected through semi-structured interviews, participant observations, document analysis and note taking. The theoretical shortcomings defined by literature that relate to barriers to organisational learning are discussed in the work. One may note that a consolidating feature of organisational learning, such as reporting of issues and data capture, are not adequately discussed in the study.

Atak and Kingma (2011) conducted an ethnographic based case study in an aircraft maintenance environment, augmented by field notes, document reviews and interviews. Tensions between quality assurance and maintenance management were identified and the prevailing safety culture examined in the context of "*integration, differentiation and fragmentation*". The study offers a comprehensive picture of the applied challenges experienced by aviation safety staff from an "*embedded*" perspective. However, the measures to prevent bias and understanding the issues are not well-defined in the publication.

Pickthall (2014) examined the mixed methods approach using a structured interview devised from an academic format. This study examined issues that arose when aircraft maintenance staff interacted with complex aircraft systems for defect rectification. Occasionally a "*no fault found*" determination has been found to be made. However, the fault-finding inputs in that case were ineffective, and the fault returned soon afterwards. The research considered the management influenced behaviours such as time pressures, poor communication, failure to adopt and share best practice, inadequate training, and reluctance to change. The work uncovered that indispensable resources, such as aircraft test equipment, integrated onboard diagnostic systems and maintenance manuals often fail to support maintenance staff when undertaking diagnosis tasks. The results suggest that these elements can actively constrain maintenance staff when they attempt to consistently manage effective and timely defect rectification. Moreover, the results are well presented and worthy of consideration when developing training material in support of learning from incidents.

Størseth and Tinmannsvik (2012) performed a Qualitative study, using semi-structured interviews in marine and rail industries domains, to examine how individuals retrospectively look back and consider learning from events. Learning indicators for the study were developed by the authors in an earlier related study. The research methods were augmented by theoretical studies and document analysis. They have found that learning within organisations takes place within the parameters of "*actor-context constellations*" where there are no defined start and finish points. This assumption is not sufficiently balanced against the need to formally consider the exigency for structure when developing learning from incident outcomes.

In their research study, Zwetsloot *et al.* (2017) endorse the importance of learning when implementing a "*zero accident vision*" in nonaviation-related domains. The work also highlights safety commitment, communication, and safety culture as learning enablers. Research design was a mixed method approach using a quantitative survey supported by interviews and workshops. The qualitative component of the research verified that learning was evident throughout the featured organisations. "*Learning by doing*" was considered a more effective approach in support of learning from incidents where employees are motivated to fully engage in the process, and supervisors can moderate theme-based safety dialogue. An extensive survey performed across 27 organisations. The qualitative methods (interviews & workshops) applied although they were not formally analysed, their synopses were used to validate the survey results. The survey component of the research records high scores relating to learning action; however, there were differences noted between staff's perception (and management) of learning action in approximately 25% of cases. Moreover, there was less diversity recorded across the learning condition dimension. The researchers considered this analogous to organisational commitment to safety. Safety commitment, communication, culture and learning were examined as individual aspects of implementing a zero-accident environment. However, their cumulative relationship was not fully examined, and the impact is not discussed sufficiently.

Hobbs and Williamson (2002) conducted a mixed method study examining the application of a previously developed "*three-way distinction*" of unsafe acts questionnaire in an aircraft maintenance context. An initial questionnaire was developed through the application of a disciplined confidential critical interview technique with 72 aircraft maintenance mechanics. The results yielded 48 elements (validated by air accident experts) and transposed into a maintenance behaviour questionnaire distributed to 4,600 licensed and 300 unlicensed aircraft maintenance mechanics (1359 questionnaires were returned). The principle component analysis was the method used to reduce the number of variables in the dataset for analysis by extracting those considered important to the study. The authors' choice of analysis does not appear to consider the competence in the context of skill-based errors and complex situations such as automation. However, the focus the publication brings on the need for aircraft maintenance staff to be aware of the cumulative effect of "*seemingly insignificant*" incidents fortifies the need to be proactive when it comes to learning from incidents.

2.3.3 Learning from Incidents

The objective of Lukic *et al.* (2012) study was to highlight factors considered to be important for effective learning, e.g., participants, process, incident and knowledge. Staff involvement and trust were positive attributes capable of supporting learning. Attributing blame and poorly developed root causation were found to detract from learning. The research also examined impact of formal and informal learning initiatives. Informal learning was found to be more difficult to record and codify and potential for learning could be limited in some cases. In their paper Lukic *et al.* (2012) highlighted that the "*over-simplification*" of incidents and contend it is often the reason incidents are mis-understood when attempting to translate incident and accident data into knowledge and learning. It is noted there is an absence of information on the structure applied to the quantitative analysis and how rigour was applied to the process. However, the authors do clarify the analysis was both data and participant driven.

The Gerede (2015) study considered some of the challenges associated with the successful implementation of safety management systems (SMS) in aircraft maintenance organisations. The SMS structure is comprised of "*safety policy and objectives, safety risk management, safety assurance and safety promotion*". Safety risk management and safety assurance were found to be important elements underscoring the effectiveness of day to day activities. Failure to create a just culture and fear of punishment for reporting share a common cultural association. The situation is attributed to a potential combination of lack of trust and negative perceptions associated with organisational culture. Moreover, Gerede (2015) identified that the absence of communication and trust may present implementation challenges within the maintenance organisations. If a just culture does not exist at national aviation authority state level, then it is questionable if the implementation of an SMS would be effective. It is unclear if the four structural elements of safety management were fully considered during the training or the data gathering phase of the study. This may account for the absence of any direct reference to learning from incidents in the study's findings.

Drupsteen *et al.* (2013) conducted case studies with selected individuals in various domains, including transportation. Their survey considered the following elements: steps in the process where learning is lost, formal organisation of steps, efficiency of steps on a daily basis, difference between espoused and actual performance of steps and differences amongst featured areas. In their work they also state that "many incidents occur because organisations fail to learn from past lessons", because the traditional approach often stops short of preventing future incidents. The research paper presented a model that examines the investigating and analysing incidents, planning and prevention, intervening and evaluating steps in a learning process. The evaluation stage was found to be a primary learning bottleneck and reporting of incidents being next. Results indicated daily practice of learning was good but follow-up steps in the process are often neglected in comparison to incident analysis. There was a significant difference between how well the investigation and incident analysis stage and the evaluation stage were performed and organised.

In their work Ward *et al.* (2010) offer a concise overview of key aspects of aircraft maintenance practice and present an accurate snapshot of the development and architecture of pertinent regulation. Understanding the aircraft maintenance system complexities is an essential precursor to implementing improvements. Organisational processes cannot be explained in terms of a linear approach due to the non-linear characteristics of flexibility and variability of comprising elements. It was found that the resulting relationship between the individuals and the systems have a direct impact upon the system and prevailing environment. Their model comprised of the following elements: system level, process activity, dependencies and stakeholders. Four reporting veins were uncovered focusing on unique aspects of: product airworthiness and system performance, i.e. data inaccuracy, quality assurance, personal injury and occurrence reporting and suggested changes were highlighted. The researchers found that regardless of how an issue presented, staff continue to experience performance constraints if communication remains poor.

Jacobsson *et al.* (2012) acknowledge the degree of interest invested in learning from incidents but question the efficiency of learning from incidents in some organisations. They found that event investigations often stop short and only partially deal with some of the elements affecting the event. Although unwelcome events are less prevalent, less severe events provide learning opportunities. Analysis of the learning cycle is valuable and such an approach can offer an insight into inherent precursors to accident conditions. They present a model featuring: reporting, analysis, decisions, implementation, and follow-up in an incident learning cycle format. Assessing effectiveness of an incident learning cycle was designed from analysing each individual step against the following dimensions: scope, quality, time and information of the first cycle loop. A general assessment of the second learning loop was performed using participant interviews. Subject matter experts applied their judgement in support of developing weighting factors for each of the model elements. The paper refers to the analysis of incident learning systems but the purpose of conducting the safety audit is not specified. The relationship (if any) between the outcome of the safety audits and the efficiency of the learning systems does not appear to be fully articulated.

Silva *et al.* (2017) examine how organisations use accident information to reduce the occurrence of unwelcome events. They suggest it is necessary to achieve a balance between adequately resourcing safety initiatives and maintaining acceptable levels of safety. They suggest that factors such as organisational culture, just culture and event data, if managed can contribute to a reduction in events. Learning within organisations should address effective information processing and interpretation. Combining technical and social strategies resulted in uncovering four patterns of practice that corresponded to different levels of learning.

In their work, Drupsteen and Wybo (2015) conclude organisations use experience gained from past events in order to improve safety. They introduce the term "*propensity to learn*" which refers to an organisation's predisposition to learning and suggest an organisation can apply lessons from past events such as warning signals, mistakes, incidents and accidents. They found that hindsight can determine if an organisation did learn from an event but there are no models to assist with gauging the "*propensity*" of an organisation to learn. The object of the study was to expound two sets of indicators that would contribute to gauging an organisation's inclination to learn. Using a previously validated questionnaire the participants' perception was assessed on learning indicators. They deduced from the review of literature that organisations displaying high learning propensity were also successful with learning from experience and sharing lessons amongst staff. Indicators based on three categories (attitudes, organisational conditions & systems) utilizing six indicators were developed to gauge organisational learning. A second set of indicators was developed in support of assessing individual propensity to learn from experience, specifically measuring attitude towards each of the stages of a generic learning process i.e., detection, analysis, follow-up, evaluation and sharing information. However, as the study was based solely on the perception of staff, it is unclear if the presented indicators alone would be satisfactory to elicit enough potentially subjective data to reinforce the results.

Furniss *et al.* (2016) examined the Hollnagel (2004) Functional Resonance Analysis Method (FRAM) which explores how functional variability resonates within systems. i.e., how well elements work together in a system. They also discuss how FRAM can be modified to support complex socio technical system improvements. This is presented in the context of four principles that encase the main assumptions (equivalence of success and failure, approximate adjustments, emergence, functional resonance) from a FRAM practitioner perspective. Their study considered how human factor methods "*are functionally coupled to a broader system of human factors practice*" (Furniss *et al.* 2016). The four steps of the FRAM analysis were augmented by two additional steps: the purpose of FRAM analysis and respondent validation.

Drupsteen and Hasle (2014) examined if organisations can learn more effectively from past incidents, future incidents could be prevented. They suggest that learning can be improved if limiting factors are addressed. The learning process in different companies was analysed and discussed. The researchers used a topic list to assess if human, technical or organisational aspects were being addressed and which elements related to specific learning phases. They found that some of the main causes of the constraints to learning can be related to lack of knowledge, unwillingness to report, causation not established, uncertainty regarding follow up action. Some conditions that enable these deficiencies are centred around misplaced cultural issues, over-focus on direct causation, poorly defined safety management procedures for example. The benefits of considering all active and latent failures as direct and indirect causes, respectively, are unclear. The study concentrated on the latency of causation. The authors state learning from incident initiatives should exercise a more generic effort to support prevention. However, one of the limitations stated was the lack of homogeneity amongst the participating organisations.

2.3.4 Just Culture

Ward *et al.* (2010) endorse the perception that aircraft maintenance is a "*highly regulated, safety critical, complex and competitive industry*". They also state that to positively perpetuate the above attributes, it is necessary to further develop an operational model that can account for "*what is meant to happen and what actually happens*". A just culture is defined as "*where people feel they can report mistakes made without fear of punishment",* (deliberate acts of damage or violations are different). The researchers proffer that a just culture can be considered as an effective enabler of good quality incident reporting.

Gerede (2015) examines some of the challenges associated with the implementation of the ICAO SMS standards and recommended practices which support the aviation industry and regulators to transition from prescriptive oversight methods to those based on performance metrics. These challenges relate to the successful propagation of a just culture which is considered as a basic principle of successful SMS implementation. The study strongly suggests that a failure to foster a just culture would be considered to have a negative impact upon effective data collection (reporting), organisational learning and the subsequent ability to learn from incidents.

Silva *et al.* (2017) put forward the value of information gleaned from incidents in support of learning and future event prevention. They examine how organisations utilise information and the strategies that assist with the propagation of lessons. They also highlight the need for organisations to encourage a learning culture and suggest the positive contribution made by reporting. It was found that a seminal element of organisational learning is a just culture, where errors and mistakes can be reported, and violations are managed fairly. In parallel, it is suggested that proportionate organisational responses are required to balance safety and accountability.

In their work, Drupsteen and Hasle (2014) proffer that learning from past incidents can assist with understanding potential future events and possibly reduce their consequences. The study examines the causes associated with organisations failure to learn from previous events. Trust and openness were identified as key elements necessary for organisational learning. In the absence of these values, under-reporting is often evident. The researchers point out that the presence of what they term a "*blame culture*" also inhibits learning as potential reporters fear of being treated un-justly for their actions.

2.3.5 Precursors

Ward *et al.* (2010) suggest improvements can be gained when organisational factors with a potential to contribute to incidents are understood. They consider these elements in the context of the Reason (1997) taxonomy (immediate, workplace & organisational) of factors as systemic precursors. An improved understanding of these elements can also shift the focus of unwarranted blame from "*the individual*" within the system. Aviation maintenance management systems are increasingly adopting an approach where identifying systemic precursors contribute to a just outcome.

The main purpose of the Drupsteen and Wybo (2015) study was to develop a set of indicators capable of determining an organisation's "*propensity to learn*". The researchers argue that the most effective set of indicators are those that could be proactively considered as "*leading indicators*". Precursors that represent activity-based inputs can signal early degradation of safety systems.

One of the main aims of the Hobbs and Williamson (2002) study was to ascertain if unsafe acts could be predicted as a result of analysing self-reported unsafe acts. Their analysis of demographic variables suggested that the occurrence of routine and exceptional violations was associated with a participants age. Higher levels of associated behaviours were linked with younger participants. The researchers were able to identify potential precursors to aircraft quality issues by association with less than optimal performance of aircraft maintenance staff. The analysis implied a distinction exists between what are termed routine and exceptional violations. The former tends to be more frequent and can be associated with short-cuts linked to routine tasks. The latter group are of a high-risk nature but occur less frequently.

2.3.6 Common Limitations Identified in the Reviewed Publications

Although there was a distinctive scarcity of information across the reviewed literature relating to the domain under primary investigation, enablers, and challenges to learning in the featured preserves were well noted, learning from incidents across all domains shares a kindred desired outcome of delivering lessons that help prevent recurrence of similar incidents in the future. However, throughout the review, a few common limitations were discovered in the literature, summarised as follows:

i. All research papers do not follow the same discipline of section title and content
ii. Few of the reviewed publications feature enough detail in the methodology sections to aid with the exact replication of the featured study.
iii. Details of piloting and testing data gathering instruments such as semi-structured templates were scarce.
iv. The robustness of some analyses was difficult to determine.
v. Where the study featured participant perceptions, gauging the efficiency of lessons learned was not well supported in the text.
vi. Safety culture and just culture are mentioned as pivotal to learning. However, the is no solid mechanism featured in support of objectively measuring either cultural component in an aircraft maintenance and continuing airworthiness management environment.
vii. The literature review uncovered many instances of formal learning. It was noted that informal learning practices were not well represented.

2.4 Conclusion

The primary aim of learning from incidents is to support actions that contribute to preventing recurrence of unwelcome events. The literature review revealed the existence of a solid formal architecture capable of delivering lessons within the featured domain activities. However, learning from incidents is not specifically articulated as a requirement and therefore presently not all elements required are explicitly articulated with the regulatory code. Although some domain requirements mandate formal training, informal learning initiatives are not required to be capitalised upon. Additionally, inadequate incident causation can deflect from potential learning opportunities arising from reporting. Poorly resourced efforts to establish appropriate causation are recorded as a central impediment to learning. The importance of reporting (incidents) and enabling facilitators such as the presence of a just culture cannot be overstated. Encouraging a reporting culture also reflects positively on the potential to learn from reported incidents. The literature review also revealed the prevalence of similar constraints to learning in other industries. Lukic *et al.* (2012) highlight the increasing focus on learning from incidents in the health, safety and environmental areas of the energy industry. They put forward factors they consider to be important for effective learning which bring a focus on; the participants of learning, types of incident, types of knowledge and learning process. The Drupsteen *et al.* (2013) industrial research (chemical, construction, energy, governmental metal, transport) states that "*many incidents occur because organisations fail to learn from past lessons*". They point out that the traditional approach to learning often features only a careful analysis and formulation of lessons in the hope future incidents will be prevented. They suggest that, in addition to focusing on prevention of re-occurrence, the learning process should be improved which in turn can contribute to making an organisation safer. Others such as Jacobsson *et al.* (2012) question the efficiency of learning from incidents in some organisations (petrochemical, food and drug, energy) but suggest there is value in the analysis of the learning cycle. Such an approach can offer an insight into inherent weakness that often enable accidents. Silva *et al.* (2017) examine how organisations (manufacturing. construction, production, distribution of energy) use accident information to reduce the occurrence of unwelcome events. They acknowledge there is a need to achieve a balance between adequately resourcing safety initiatives and maintaining acceptable levels of safety. In healthcare, Drupsteen and Wybo (2015) suggests an organisation can apply lessons arising from past events such as warning signals, mistakes, incidents and accidents. Hindsight can assist with determining if an organisation did actually learn from an unwelcome event, and their study expounds two sets of indicators that could contribute to gauging an organisation's inclination to learn. By considering the outputs of research in domains parallel to continuing airworthiness, the benefits of proven approaches in other industries could be leveraged and applied without further delay.

Many aspects of current literature are developed from a linear or sequential view of how an accident/incident occurs. This of course might be an appropriate place to start to examine the retrospective aspects of learning that an unwelcome event can provide. However, more proactive models such as the Hollnagel *et al.* (2015) FRAM Model as highlighted by Furniss *et al.* (2016), are very capable of delivering more sustainable lessons. Nevertheless, it is evident from the literature search and review that research in the aircraft maintenance and continuing airworthiness management arena are yet not well represented in respect of learning from incidents.

One potential benefit of digressing from the traditional view of causation is that models like FRAM can be applied in support of specific analysis frameworks capable of deciphering: what went wrong, hazards that may have not been previously considered and the feasibility of potential solutions to prevent recurrence. As human systems and artificial intelligence continue to occupy shared workspaces, an appreciation of exactly how the system works is essential in order to deliver effective lessons when unwelcome events do occur. Further research in the continuing airworthiness area utilizing forward looking frameworks such as FRAM will have a positive impact on better understanding event causation. It will also present a need to examine and augment legislative requirements to support the needs of regulatory and ethical oversight of systems that employ a blend of human and autonomous functionality. It is believed that the systematic review could be used to refine terms of reference for a European legislative working group tasked with improving the content of the implementing regulations in the area of learning of incidents within the context of SMS's in aircraft maintenance and continuing airworthiness management organisations.

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Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

Note 1: A fundamental principle of applying effort to accident and incident investigations is to establish what happened and using this information to assist with preventing recurrence of the event. However, two appointed entity practitioners for the investigation of accidents and incidents were excluded from the study. The following criterion was applied in support of this:

State Investigation Authorities (SIA's)

- SIA's are appointed to investigate ICAO Annex 13 related accidents and incidents. The scope of this body of work was bound by the parameters of continuing airworthiness activities and related events only.

National Aviation Authorities (NAA's)

The exclusion of national aviation authority inspectorate staff from the data gathering phase was based on the following elements;

- The national aviation authority in the jurisdiction of the study did not support the study. The absence of an endorsement from senior authority figures was felt could pose a significant challenge for potential participants (Based on previous experience).
- The culture within the subject national aviation authority is underpinned by a compliance paradigm. A focus on achieving a high score in EASA standardization audits, ICAO oversight audits and DOT Section 32 audits is embedded within many of the comprising departments and supporting philosophies. Moves are afoot to shift the basis from pure compliance to a blend of compliance and risk-based oversight methodologies. As previously noted by UK CAA (CAP1642

2018) there are a number of 'structural' items that must be addressed prior to such a paradigm shift being achieved. Namely, cultural, procedural and governance organisational components. Consequently, it was considered that the application and use of the continuing airworthiness requirements in industry may have moved ahead of the regulator because risk currently informs many of the decisions and actions applied in an ever-increasing number of continuing airworthiness organisations. It was therefore decided that the inclusion of aviation authority staff may introduce a distortion into the outcome of the study results.

- During the 'ideation' process in the early stages of planning the PhD, it was apparent that if the researcher was aligned with the national aviation authority, the data-gathering and its quality might be impeded amongst industry participants.
- From a professional point of view, the researcher felt that 'unsponsored' research would be viewed as unadulterated and more acceptable amongst industry practitioners and the academic communities.
- Many opportunities for further research tend to be revealed during academic studies. However, due to time constraints, self-funding restrictions, family obligations and employment commitments, such studies must be bound by some form of parameters.

Note 2: A degree of convention is required when developing inclusion & exclusion criteria in order to avoid bias and introduce a level of uniformity to ensure a literature review remains systematic. Therefore, the researcher considered it important to maintain the integrity of the study by applying the criteria below. The justification and rationale for the selected criteria is as follows:

Inclusion rationale	
Research studies	The systematic literature set out to establish a baseline for the study. In order to present a productive outcome, research studies that arose as a result of applying defined search terms was deemed to be a productive approach.
Qualitative and mixed methods	Qualitative studies enable a researcher to make sense of reality and to explain the phenomenon observed. This approach is helpful when developing explanatory models. These aspects were considered to be congruent with the tasks the researcher was pursuing in support of the study. The decision to include mixed methods was based on the idea that they are useful in understanding any contradictions that may exist between quantitative results and results arising from qualitative methods.
Perceptions and experiences	Studies that captured participant experiences and perceptions were of interest because the thesis research intended to capitalise on these strands. The researcher was interested in the impact on previous studies and also how this locale might impact the literature review content.
Reference to just culture	Just culture is a fundamental in learning from incidents within aviation environs. The researcher was interested in how just culture impacts other high-reliability domains.
High reliability settings	Academic information and protocol for conducting literature reviews in the continuing airworthiness domain is scarce. Examining how other domains consider learning from incidents was deemed worthy of inclusion.
Published post 1992	At the time of the literature review twenty-five years was considered to be a reasonable period to consider learning from incidents literature.
Peer reviewed publications	The researcher considered peer reviewed publication inclusion essential because such publications tend to focus on specific research questions and present accurate conclusions based on robust research efforts.
Industry based settings	The position of industry is important. Growth and development can manifest ahead of academia and regulatory function within the aviation segments under focus.
Original studies	Reviewing original studies allows a researcher to assess the independence of thought and originality of findings as opposed to considering these through the lens of another researcher's position.
Exclusion criteria	
Literature reviews	These criteria were intended to support a systematic review of literature as summoned by search terms on specific databases. In order to preserve the originality of the initiative and prevent any possibility of introducing bias from other reviews, it was decided to not include this facet of literature.
Quantitative methods	The thesis research was primarily engaged with assessing perception of a cohort in a particular environment. The outcome of quantitative studies was not considered capable of augmenting these efforts.
Focused on decision-making and legislative requirements	A content analysis of regulatory material mandated for use by approved entities within the segment was conducted separately.

Concluding statement

In this Chapter, a systematic literature review of learning from incidents has been presented. The outputs from the chapter make a contribution to the body of knowledge in terms of highlighting enablers and impediments to learning from incidents (LFI). The following chapter 3 examines the European legislative requirements that affect the ability of organisations to learn from incidents.

Preamble and Statement of Author's Contribution Chapter 3

Chapter 3 details a critical and independent evaluation of regulation and practice that can affect the ability of European Union regulated aircraft maintenance and continuing airworthiness management organizations to learn from incidents.

Author Contributions: Conceptualization, J.C. and K.I.K.; methodology, J.C.; formal analysis, J.C.; investigation, J.C.; validation, J.C and K.I.K.; data curation, J.C.; writing—original draft preparation, J.C. and K.I.K.; writing—review and editing, J.C. and K.I.K. All authors have read and agreed to the published version of the manuscript.

Chapter 3. Learning from Incidents in Aircraft Maintenance and Continuing Airworthiness: Regulation, Practice and Gaps

Abstract.

Purpose - The ability to learn from previous events in support of preventing future similar events is a valuable attribute of aviation safety systems. A primary constituent of this mechanism is the reporting of incidents and its importance in support of developing learning material. Many regulatory requirements clearly define a structure for the use of learning material through organisational and procedural continuation training programmes. This work reviews aviation regulation and practice, highlighting the importance of learning as a key tenet of safety performance.

Design/methodology/approach – Applicable International Civil Aviation Organisation requirements and the European Union (EU) regulation in aircraft maintenance and continuing airworthiness management have been critically reviewed through content analysis.

Findings – This review has identified gaps in the European implementing rules that could be addressed in the future to support a more effective approach to the delivery of lessons in the aircraft maintenance and continuing airworthiness management sector. These include light-touch of learning and guidance requirements, lack of methodologies for the augmentation of safety culture assessment, absence of competence requirements for human factors trainers and lack of guidance on standardised root-cause analyses.

Practical implications – This paper offers aviation safety practitioners working within the European Aviation Safety Agency regulatory regime an insight into important matters affecting the ability to learn from incidents.

Originality/value – This paper evaluates critically and independently the regulation and practice that can affect the ability of EU regulated aircraft maintenance and continuing airworthiness management organisations to learn from incidents. The outputs from this research present a fresh and independent view of organisational practices that, if left unchecked, are capable impeding the incident learning process.

Keywords Airworthiness, Aircraft, Accident investigation, Aircraft maintenance, Aviation Safety.

Paper type General review

3.1 Introduction

Throughout aviation history, learning from incidents has been considered to be one means of augmenting what Perrow (1999) terms "safety devices". "*Experience is the best teacher*" according to Kleiner and Roth (1997) as they claim that the causes of the mistakes are often not fully accounted for and continue to be present in the absence of learning. In general terms, Nonaka (1991) suggests that creating new knowledge extends past a mechanistic approach and is strongly related to employees' insights. An effective enabler of learning in this area is the collation of information on incidents. Details of the related processes, environment, procedures, competencies and implementing timely corrective actions all have a positive impact on learning and are generally intended to help prevent recurrence in the future.

Learning from incidents is mainly associated with post incident learning. When we think of the word "*incident*", it conjures up the notion of an action that may have grave consequences. Similarly, the word "*accident*" is often used in the context of an unplanned event or set of circumstances. In many industrial sectors and business domains, these descriptors are used with a degree of interchangeability when the words are applied to describe events. In aviation, there are clear high-level definitions for both event categories, and these are based on potential for harm. The International Civil Aviation Organisation (ICAO) defines (ICAO 2010):

1. Accident, as "*an occurrence associated with the operation of a plane that takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:*

- *A person is fatally or seriously injured.*
- *The aircraft sustains damage or structural failure.*
- *The aircraft is missing or is completely inaccessible".*

2. Incident, as "*an occurrence, other than an accident, associated with the operation of an aircraft that affects or could affect the safety of operation*."

However, the presence of international legal obligations for maintaining safe aviation systems are intended to support individual state responsibilities when developing statutory safety requirements. In Europe, international standards and recommended practices (SARP) are transposed into national/European law, forming the basis of state oversight and operator obligations. Aviation regulations and the laws they are derived from are intended to establish standards and enable a benchmark for safe operations. Apart from setting out to support acceptable levels of safety within aviation segments, some references to learning are contained within the implementing regulatory framework.

This paper reviews the evolution of aviation regulation, with a focus in the aircraft maintenance and continuing airworthiness sector, examining the way in which regulations mandate learning from incidents. It also discusses how lessons are translated into best practice and what aspects of regulatory oversight affect the sector. The present work, utilising a systematic content analysis approach, offers a new and independent view on important matters that may have a negative impact on the incident learning process.

3.2 Material and Methods

The paper features the concept of learning from incidents as grounded in enabling legislation. Within this area, operational activity capabilities are determined by very specific regulations and recommended practice. The static architecture of these domain requirements considered in the analysis thereby sets out the parameters of the documents qualifying for review.

To perform an efficient and effective review, a structured approach was required. Okoli and Schabram (2010) state that "*a dedicated methodological approach is necessary in any kind of literature review*". In the editorial section of Weber (1990) the editor proffers, "*content analysis classifies textual material, reducing it to more relevant manageable lots of data*". However, the author (Weber 1990) later reveals the presence of an inherent issue with the method by suggesting that words, phrases or other units of text are assumed to have a similar meaning when classified in the same category. The issue being that such a distillation resulting from category-based reduction could semantically limit the inference arising from the analysis. As the primary function of aviation legislation is to support the achievement of acceptable levels of safety, it was established this constraint would not negatively impact the scope of the review.

At an international rule-making level, ICAO develops aviation safety, security and environmental protection requirements. The organization also moderates (SARP) relating to the technical aspects of aviation, which form the basis of ICAO state signatory primary aviation legislation e.g. Chicago Convention (ICAO 1944), Annex 19 (ICAO 2013a). Additionally, as the paper relates to a European jurisdiction, it is also necessary to consider the requirements underpinning aircraft maintenance and continuing airworthiness management. Basic regulations such as European Union (EU) Regulation 2018/1139 (2018/1139), implementing EU Regulation 1321/2014 (1321/2014) were essential inclusions when analysing activity in the sector.

3.2.1 Inclusion/exclusion criteria

Stansfield and Thomas (2012) suggest a need to develop inclusion/exclusion criteria to support a thorough documentary review. Having a set of criteria helps to eliminate potential researcher bias during the review process. Inclusion and exclusion criteria were developed in concert with the objectives presented below and guidelines contained in Meline (2006):

- To review salient underpinning international aviation safety management requirements for the domain specific area.
- To review the appropriate European aircraft maintenance & continuing airworthiness safety management requirements.
- To identify regulatory gaps and potential enhancements capable of improving learning from incidents.

The inclusion and exclusion criteria used in this study are presented in Table 3.1.

Table 3.1. Inclusion and exclusion criteria.

Included	Excluded
ICAO Chicago Convention (ICAO, 1944) ICAO Annex 13 (ICAO, 2010) ICAO Annex 19 (ICAO, 2013a) ICAO DOC 9859 (ICAO, 2013b) EU Regulation 2018/1139 (EU, 2018) EU Regulation 376/2014 (EU, 2014a) EU Regulation 1321/2014 (EU, 2014b) EU Regulation 996/2010 (EU, 2010)	Non-legislative domain publications relating to aircraft maintenance and continuing airworthiness management.

3.2.2 Document review

Bowen (2009) relates the analysis of documents to giving voice and meaning around a topic under assessment. The subject documents supporting the review were selected as those mandated by the enabling requirements for the aviation domain activities. The review process took advantage of the following steps:

- Assemble the texts under review.
- Verify their applicability.
- Consider the presence of reviewer bias and mitigate.
- Ensure the process is supported by adequate domain knowledge.
- Consider any ethical issues that arise.
- Document the outcome of the review of each individual requirement with the scope of the analysis.

The following section presents the output from this process.

3.3 The regulatory framework

3.3.1 International Civil Aviation Organisation

The ICAO member states, and additional groups are involved in the rulemaking process. These stakeholders work together to reach a consensus in support of efficient, effective, and sustainable aviation regulation. The related practices and policies are applied by member states within the parameters of their incumbent legal frameworks. Each member state in cooperation with its civil aviation authority transpose the requirements into national implementing regulations. For example, Ireland's Air Navigation and Transport Act (1946) and subsequent amendments transposed the Chicago Convention (ICAO 1944) elements into Irish law, comprising of Acts, Orders and Statutory Instruments. The regularising of a standard approach to aviation regulation in Ireland which the Act enabled was an antecedent to the current body, the Irish Aviation Authority (IAA), which today discharges the State's aviation oversight responsibilities in Ireland.

3.3.1.1 ICAO Chicago Convention – the basis for formalising structured aviation regulation

The work initiated by the Chicago Convention signatories (ICAO 1944) was monumental in terms of the foundations it laid for regulations supporting a common global air transport system. The Convention enabled the establishment of ICAO, which has worked since its inception to support, foster and manage the international cooperation necessary to augment safe air transport. Its main remit is to "*secure international co-operation and the highest possible degree of uniformity in regulations and standards, procedures and organization regarding civil aviation matters*" (ICAO 1944). This has contributed to aviation continuously pursuing levels of safety that made it one of the safest forms of transport.

The Convention is supported by nineteen annexes that contain SARP's. The SARP's provide guidelines for all activities that relate to air operations, licensing, navigation, aircraft maintenance and safety management. While the Convention does not contain any technical requirements for learning from unwelcome events/incidents, Annex 13 (ICAO 2010) (aircraft accident and incident investigation) and Annex 19 (ICAO 2013a) (Safety Management) provide a framework to harvest information that can be applied to learning initiatives and prevent similar events.

3.3.1.2 ICAO Convention Annex 13 - aircraft accident and incident investigation

ICAO Annex 13 (ICAO 2010) assists states with the application of a consistent approach to investigations. The sole purpose of conducting an ICAO Annex 13 investigation is to use the outcome to prevent accidents and incidents through applying lessons learned and not apportion blame or liability. Causation and contributing factors must be established for aircraft accidents and serious incidents so that every effort can be applied to prevent recurrence. The establishment of causal factors is most efficacious when a standardised approach is applied for accident prevention.

The ICAO Annex 13 defines the responsibilities, obligations and entitlements of affected parties when safety events are investigated. It also contains a requirement to produce a final report that may contain safety recommendations. In effect, the state receiving a safety recommendation is obliged to implement procedures to monitor the progress of tasks required to address the issue. From an accident prevention perspective, states are obliged to establish and maintain an accident and incident database. This database is intended to facilitate the analysis of event information and assist in revealing safety deficiencies. These outputs assist states to promulgate lessons to be learned in support of accident and incident prevention. In addition to the accident prevention capabilities of the ICAO Annex 13, further provisions for the collection, analysis and prompt exchange of safety information are contained in the ICAO Annex 19 Safety Management (ICAO 2013a) and the ICAO Document 9859 Safety Management Manual (ICAO 2013b).

3.3.1.3 ICAO Convention Annex 19 - safety management

As the aviation industry's interactions and complexity continue to increase, safety management practices are evolving so that risk can be managed more strategically. Safety risks can be best addressed if managed proactively through adequate regulatory infrastructure and appropriate enabling elements. In 2010, ICAO recommended the development of a dedicated Annex to define state safety management responsibilities. This was achieved by consolidating safety management detail from six other Annexes into Annex 19. Each states' safety management responsibilities are represented in the form of pillars comprising of the following: a state safety programme (SSP), objectives and resources, risk management, safety assurance and promotion. The ICAO Annex 19 lays out detail to ensure the continued availability of safety data and information required to augment safety management (ICAO 2013a). This standard requires
states to establish a safety data collection system capable of capturing, storing, aggregating, and analysing safety data. The purpose of collectively analysing safety data is to identify systemic hazards that may not be revealed through the lens of an individual entity analysis. ICAO Annex 19 also requires states to accord protection to data derived from reporting. A high degree of protection is considered necessary to foster an active reporting environment, in turn, supported by a just culture. Additionally, states are encouraged to take steps to promote a positive safety culture and encourage reporting. ICAO Annex 19 makes provisions to share safety information across states, when mutual safety matters of interest are identified.

3.3.1.4 ICAO Document 9859 - safety management manual

The ICAO Document 9859 (ICAO 2013b) (safety management manual) provides guidance on the development and implementation of an (SSP) and it is applied in conjunction with ICAO Annex 19 (ICAO 2013b). The manual's structure reaffirms the basics of the effective application of safety management. SSPs and safety management systems (SMS) are considered in relation to their interaction with other annexes. A philosophy for implementing SMS by the aviation industry and a progressive approach for states implementing and maintaining SSP's is described. The productive role that ICAO state civil aviation authorities play in the implementation of SMS for industry is also emphasised.

ICAO Document 9859 (ICAO 2013b) states, "*culture is characterized by the beliefs, values, biases and the resulting behaviours that are shared by members of a society,* *group or organization*". An understanding of an organisation's cultural components and their importance to safety management is reaffirmed here. Improvements to the safety management process can be achieved when safety is instilled as a value within an organisation (ICAO 2013b). Learning from incidents is an active output from a positive safety culture. Progressive state and industry stakeholders are actively directed to pursue improvement. ICAO Document 9859 (ICAO 2013b) encourages stakeholders to leverage safety benefits from remaining vigilant to hazards by utilizing safety data arising from reporting, data analysis and investigations. The document attributes improvement in the civil aviation safety records to "*a continuous learning process based on the development and free exchange of safety information*".

One area in the ICAO Document 9859 (ICAO 2013b) where reporting, analysis of data and learning make an effectual contribution to safety is when entities collectively consider deviations (operational and otherwise) from an organisation's baseline safety performance. The resulting 'chasm' is often termed "*practical drift*" (Snook 2000). Experience gleaned from reporting informs us that this condition can occur for various reasons, i.e., technology not operating as intended, procedural deviations due environmental conditions, change, and interaction with other systems. The document reaffirms the importance of capturing deviations or drift as early as possible. The predictive value of this information cannot be overstated when early intervention to restore a satisfactory condition can be made without delay. Additionally, the resulting lessons learned can be applied to system, procedural and structural improvements to prevent event recurrence.

3.3.2 European Union Regulations

Member states of the EU are obliged to comply with regulatory outputs from the European Aviation Safety Agency (EASA). EASA, among other functions, supports the European Commission (EC) in the technical development and compliance oversight of aviation regulations and monitors and approves organizations involved in the maintenance of aviation products, with the desired outcome of safe operations. Moreover, a major aspect of EASA's work is to analyse safety and research data.

3.3.2.1 EU Regulation 2018/1139 - common rules in civil aviation in the EU

EU Regulation 2018/1139 (2018/1139) aims to establish and maintain a high level of safety in the EU aviation. This regulation covers design, production, maintenance and operation of aircraft and their parts. It also affects aircraft operating in and out of the EU and defines the role of EASA. Amongst EASA's administrative functions is its responsibility to perform safety oversight of aircraft maintenance and management organisation activities, managing these responsibilities through implementing regulations. Similar to the ICAO requirements, EU Regulations (376/2014) and (1321/2014) facilitate the exchange of safety information amongst EASA and the national civil aviation authorities. Therefore, this regulation enables EASA to moderate a structure that collects, exchanges and analyses safety related information (2018/1139). It also mandates that there are provisions ensuring the collected information and data is securely stored and protected. An electronic database is recommended, as an efficacious repository to manage and exchange data in support of preventing recurrence of events.

3.3.2.2 EU Regulation 376/2014 - reporting, analysis and follow-up of occurrences in civil aviation

The EU, in recognition of its duty of care to the travelling public, acknowledges that it must continue to improve aviation safety performance. Based on the imminent increase in aviation activity, significant challenges loom if the EU is to only preserve current levels of safety. Thus, to remain abreast of the future challenges, EU is transitioning towards a proactive aviation risk-based safety system (EU 2015). The desired outcome is that member states and industry will work together to collect data for early identification of hazards and implementation of mitigating actions. This enables focusing oversight efforts where they can be most effective for safety management purposes. The EU Regulation 376/2014 (376/2014) was developed to enable the collection, analysis, and follow up of occurrences for a performance-based safety oversight system. This regulation recognises that, "while the ability to learn from an accident is crucial, purely reactive systems have been found to be of limited use in continuing to bring forward improvements" (376/2014). However, it suggests that these reactive systems should be bolstered by "*proactive systems which use other types of safety information to make effective improvements in aviation safety*" (376/2014). This is largely left up to each organisation to develop their own "proactive system" in conjunction with the ICAO Annex 19 on SMS. One collective element addressed by this regulation is the reporting of incidents and accidents.

A main tenet of the reporting system is the ability of an individual to report any hazard or potential hazard in a "*free and frank*" manner. This element of a safety culture's philosophy is to be supported by "*just culture*", where the outcome for the individual is not based on punitive measures or being inappropriately punished for reporting or co-operating with occurrence investigations. This regulation has provisions for mandatory and voluntary occurrence reports. There are discriminating conditions that must be met to determine when to report a hazard. Organisations are required to have a process to implement a timely follow-up and notification of their analysis to the aviation authority. Reporting entities are encouraged to submit reports to a portal moderated by EASA. Aviation authorities have access to the portal and the incidents and accidents are categorised in accordance with a standard aviation data reporting program (ADREP) taxonomy and uploaded to a European coordination for accident and incident reporting systems database (ECCAIRS). This database assembles (multi-modal) transport safety data.

3.3.2.3 EU Regulation 996/2010 - investigation and prevention of accidents and incidents in civil aviation

The EU Regulation 996/2010 (996/2010) supports safety by enabling efficient and effective investigations. It also requires the provision of certain information to state investigating authorities (SIAs) in a timely manner in relation to all persons and dangerous goods carried on board an accident aircraft. This regulation applies to the investigation of accidents and serious incidents as specified in the ICAO Annex 13 (ICAO 2010). The following are some of the accidents and incidents where this regulation applies (996/2010):

- Accidents occurring in EU member states.
- Accidents occurring outside of EU member states but involving an EU registered aircraft or being operated by an EU operator, where EU member states are entitled to appoint an accredited representative or have a special interest, such as where EU citizens are involved in an accident or serious incident.

This regulation stipulates that SIAs are independent from oversight or other state safety aviation roles, such as aviation authorities. SIAs must be functionally independent and capable of conducting a full safety investigation whilst being adequately resourced.

Effectively, SIAs investigate accidents and serious incidents so that lessons can be learned, and recommendations can be made to help prevent the occurrence of similar events. SIA’s release several different publications that contain this information. These reports fall into the following categories: interim and final reports, accident and serious incident reports, safety bulletins and foreign accident reports. For example, under Irish law, investigations enabled by EU Regulation 996/2010 and ICAO Annex 13 are required to be independent of judicial proceedings and are in no way intended to apportion blame or liability (460/2009).

3.3.2.4 EU Regulation 1321/2014 - continuing airworthiness and approval of organisations and personnel

The EU Regulation 1321/2014 (1321/2014) specifies the compliance requirements necessary for persons and organisations involved in continuing airworthiness activities. The regulation comprises of specific requirements for:

- Maintenance organisations (Part 145).
- Continuing airworthiness management organisations (Part M).
- Maintenance personnel (Part 66).
- Maintenance training organisations (Part 147).

Collectively addressing these requirements theoretically means the associated processes supporting airworthiness ensures an aircraft is fit for safe flight. Organisations operating under EU regulations must formally engage a (CAMO) to support the maintenance management function. The purpose of CAMO is to ensure that all mandatory requirements are addressed, and the aircraft continues to be maintained in an airworthy condition. The CAMO manages and forecasts maintenance, and through formalised agreements, ensures the necessary maintenance inputs are performed by an aircraft maintenance organisation (AMO), on time and to the correct standard.

Aircraft maintenance and continuing airworthiness activities are affected by regulations mandating the reporting of issues that could affect safety. These mandatory occurrence reporting responsibilities also extend to individuals who hold privileges within organisations, under this regulation (1321/2014). The individual requirements that enable the EASA Part 145 and Part M code activities require the reporting obligations and responsibilities to be stated in procedural form in the companies' expositions. This is to support the organisation's mandatory occurrence reporting system, which collects, analyses, and evaluates reports. The organisation must identify adverse trends and implement timely corrective actions. Both EASA Part 145 and Part M requirements encourage the distribution of internal occurrence reporting outputs to staff. Learning material is used to raise awareness of reported issues, and therefore assist with preventing a recurrence of the event or similar events.

The importance of occurrence reporting cannot be overstated when attempting to identify contributing factors and the potential emergent lessons. This regulation recognises the positive impact a functional just culture has as it encourages "free and frank" reporting. Reporting is further augmented when staff are aware that those who report will not be inappropriately punished for doing so or for co-operating with ensuing investigations. This psychological contract is further reinforced by the presence of a closed-loop process that requires the reporter to receive feedback to their report.

Figure 3.1 offers an illustration of the overall ICAO and EU regulatory landscape described in the previous section, where the interactions and relations of the requirements and regulations are shown.

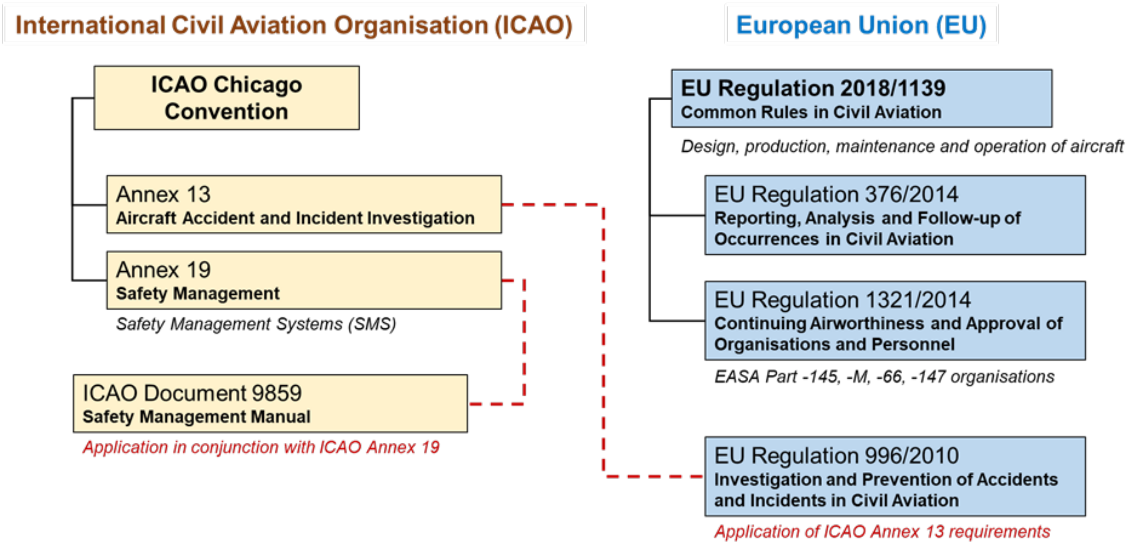

Figure 3.1. The ICAO and EU regulatory framework surrounding safety management; focused on aircraft maintenance and continuing airworthiness management.

3.4 Implementation of regulations

3.4.1 Framework and compliance

The EU Regulations 376/2014 (376/2014) and 1321/2014 (1321/2014) require the operation of a SSP, similarly to ICAO Annex 19 requirements (ICAO 2013a). The aim of SSP is to proactively discover and manage factors that may contribute to incidents and accidents and to fortify the maintenance and operational systems against errors. For AMOs (EASA Part 145) and CAMOs (EASA Part M), the associated responsibilities must be reflected within procedural form for each code. Details of these procedures are prescribed in the EU Regulation 1321/2014 (1321/2014). This detail covers basic training and competence requirements for staff and managers, reporting requirements, initial and recurring human factors (HF) and training in procedures for managing reporting systems. When organisations apply to civil aviation authorities for the privileges that relate to aircraft maintenance and continuing airworthiness management, compliance audits are performed by the authorities to ensure the applicant can perform the necessary tasks. Each approval has a 2-years cycle and authorities must perform continuous oversight to ensure that organisations remain in compliance. Each EASA Part 145 and Part M organisation must perform annually a complete programme of internal audits by their independent quality assurance system. Aviation authorities and regulated organisations apply the regulatory detail in a similar manner when measuring compliance with each code. For both maintenance and continuing airworthiness management reporting, occurrence reporting system and responsibilities are a subset of the overall audit programme.

3.4.2 Reporting

Lessons from events and incidents are derived from several sources within the aviation system. ICAO Annex 13 accidents and serious incidents are supported with the publication of thorough and independent non-biased reports. Often based on causal or contributing factors, safety recommendations may feature elements that affect the maintenance or management function or both. Depending on who the investigating authority directs the safety recommendation to, affects how the lesson is promulgated to industry stakeholders.

3.4.2.1 Internal and external reports

Internal company occurrence reporting systems that underpin the identification of issues relating to flight safety or the release of a safe product, are valuable sources of data for learning within EASA Part 145 and Part M organisations. According to the EU Regulation 1321/2014 (1321/2014), organisations are required to have a system to collect, analyse, develop interventions as required and promulgate lessons to prevent reoccurrences. When organisations deliver initial and continuation HF training, they must feature a cross-section of lessons arising from internal occurrence reporting and operating experience. Organisations also have to look outside their own specific areas and introduce lessons from other areas of the industry.

Occasionally, incidents that arise through internal occurrence (voluntary and mandatory) reporting are required to be reported to external bodies such as aviation authorities, aircraft manufacturers or SIAs. These entities will review the incident and decide if further information or intervention is required to terminate their request. All incidents reported to aviation authorities are collated and published on an annual basis. These reports are made available and operators, approval holders and individuals are encouraged to review and assimilate, as necessary. These reports are often used in support of EU Regulation 1321/2014 (1321/2014) continuation training syllabi. Moreover, in a case where it is found that aviation regulation was a contributing factor to an event, a safety recommendation may be directed to EASA. If accepted by the recipient, it can be a catalyst for regulatory amendment. The amended regulation is then brought to the attention of staff through an internal training mechanism mandated by EU 1321/2014 (1321/2014). In the case of accidents and serious incidents arising from factors relating to aircraft design or maintenance error, lessons may be learned through the conduit of mandatory communications, the Airworthiness Directives (ADs). ADs require immediate recognition and recipients are legally obligated to comply within defined timeframes.

3.4.2.2 Databases and reporting standards

Databases containing details of events with known potential and latent ancillary contributors can be monitored with the assistance of continuous analysis. For example, in the United States (US), a combined effort by various industry stakeholders, known as the Aviation Safety Reporting System (ASRS), collects voluntary reports. The outputs from ASRS set out to identify system deficiencies and corresponds directly with individuals in positions that can affect improvements and corrective actions. These reports are often of interest to organisations operating aviation products that have originated in the US.

SARP that define an ICAO state obligations have been developed as a result of the collective efforts of participating states, i.e. ICAO Annex 13 (ICAO 2010) defines the standards requiring the reporting of accidents involving aircraft with a maximum take-off weight (MTOW) of 2,250 kg and above. The same document contains details of reportable incidents deemed important for accident prevention for 5,700 kg MTOW aircraft. An accident/incident data reporting system (ADREP) is operated and managed by ICAO, with safety data from the member states received, verified, and retained in ADREP. This global repository reflects the aggregate of state-reported occurrences/incidents/accidents. The following outputs are available from ADREP:

- Annual statistical presentation of broad categories of information broken into headings, such as event types and operational phases.

- Report summaries delivered on bimonthly basis illustrating a global view of ‘significant’ reported events.
- Feedback to ICAO states in response to requests for ADREP information.

The ICAO Accident/Incident Reporting Manual (ICAO 2014) defines the report content, its composition and means of transmittal to ICAO. A taxonomy is used to standardise the inputs for reporting. One of the difficulties faced by the ADREP system administration is that some of the state reporting systems do not strictly apply this taxonomy. However, to improve harmonisation and exchange of information, regulated entities affected by EU Regulation 2018/1139 (2018/1139), have already migrated to the ICAO common ADREP taxonomy. The ADREP software platform currently in use by ICAO was developed by the EC and was made available for implementation in the middle of the 2010s. While some ICAO states process reports manually, the basic software is available free of charge and it is expected most national reporting systems will be capable of transferring data by electronic means. The outputs from the ADREP system are useful for HF training programmes and offer a solid dataset to compare national against global event rates.

3.5 Results and Discussion

Regulations empower aviation authorities to affect a certain degree of oversight to reporting and learning systems. However, in aircraft maintenance and continuing airworthiness there are a few areas where legislation does not support learning from incidents within organisations. Without a standardized approach to learning from incidents, it is questionable if the benefits can be fully realised from current efforts. Organisational and regulatory oversight does not have the mandated scope to decipher if the incident learning content of HF training is being delivered effectively. Oversight and quality assurance audits merely verify that a company is delivering HF training and because the regulations do not articulate the need to go any further, and the quality and impact of the training material is left to the organisation. This issue is often compounded by the struggle for compliance, specifically minimum compliance, which many organisations demonstrate and could be considered a by-product of regulatory gaps. The following subsections present and discuss the results from the review of the EU codes for aircraft maintenance and continuing airworthiness management.

3.5.1 Light-touch learning and guidance requirements

Safety requirements are scoped to support the achievement of an acceptable level of aviation safety. At the same time, affected industry segments will often lobby rule makers in an attempt to decrease the effect of an impending regulation. Therefore, the larger industry segments have a strong degree of influence over the final drafts of regulatory requirements. These are common challenges for the EC in the relation to rulemaking. In the case of EU 1321/2014 (1321/2014) and EU 2018/1139 (2018/1139), these must be generic enough to support the industry segments but also satisfy stakeholders other than aviation regulatory entities. The aviation industry is continuing to demand more efficiency, sometimes under the veil of corporate social responsibility but often without additional tangible safety outcomes.

The expanding regulatory oversight burden that comes with an increase in aviation activity is not sustainable if the paradigm of light-touch learning and guidance requirements continues to prevail. The EU Aviation Strategy (EU 2015) commits to a shift from the current regulatory model to a risk-based oversight system. This will direct resources at areas of risk in the industry. Effectively, this should lessen financial outlay for member states while it will preserve and further develop acceptable levels of safety if supporting regulatory frameworks evolve. Regardless, implementing rules must be amended to address a means of defining a simple life-cycle approach to learning from incidents and how learning can be measured and improved where necessary.

3.5.2 Absence of minimum competence requirement for human factor trainers

The review of EU 1321/2014 (1321/2014) highlights the absence of competence and qualification requirements for staff delivering HF initial and recurrent training. Additionally, there is no defined or accepted practice specified for assessing the depth of student learning or the assimilation of learning outcomes. HF training feedback is required to be used by the custodians of the training programmes. The intent is that the information received from students will strengthen future training programmes. In the programmes developed and delivered, the learner's ability and style are not required to be considered. Redeveloping and expanding guidance on regulatory feedback is one mechanism capable to support an improved design template that could be used in support of learning from incidents. Even though compliance with HF training syllabi requirements are verified, the current requirements do not extend far enough to support the need for increased measurable learning effectiveness to underpin risk-based oversight.

If the current regulatory requirements for the delivery of lessons learned are not redrafted to reflect a standard for the preparation of initial and recurrent HF training, assessment and competence requirements for trainers, the improvements anticipated from the risk-based methodologies shall not to materialise in full.

3.5.3 Methodologies to augment assessment of safety culture

Regulations require staff to receive continuation training at least every two years. The advent of EU requirements has stood the industry in good stead and has contributed greatly to achieving acceptable levels of safe operations. To achieve the maximum impact from training (especially material featuring lessons learned), it would assist to periodically assess the prevailing cultural conditions within an organisation. Currently there is no regulatory requirement that supports such an assessment. The EU Regulation 2018/1139 (2018/1139) refers to the "*promotion of a culture of safety*" as it relates to reporting of incidents. The term "*just-culture*" is also referred to in EU Regulation 1321/2014 (1321/2014). However, the absence of any guidelines on how to establish the strength of a just culture or details of how to assess its presence are duly absent from the requirements. An embedded regulatory approach applying an ethnographic methodology in support of safety culture assessment could qualitatively verify the effectiveness of HF training in addition to formally gauging an organisation's culture. This would need to examine issues around communication and trust within AMOs, as both HF are important for the establishment and sustainment of a healthy safety culture within organisations (Chatzi 2019, Chatzi *et al.* 2019).

3.5.4 Lack of guidance on a standard approach to root-cause analysis

Many regulations support a notion that more reporting is necessary. Reporting can be impeded for many reasons, such as, cultural, environmental and production pressures. There are pros and cons associated with increased reporting, if, however, the root causes are not correctly established, any additional effort by individuals may be futile. In cases where root cause analysis is inadequate, there is often a missed opportunity for learning. The EU Regulation 1321/2014 (1321/2014) does not stipulate guidance for an acceptable model to augment or propagate this element of learning.

It is interesting to map these four findings against the Product-Behaviour-Process (PBP) model (Purton *et al.* 2014), examining specifically looking at the regulatory interventions.

The output of this exercise is illustrated in Fig. 3.2. The first observation is that the product segment of the PBP model, namely, any changes on the design and certification of aircraft and products, would not be affected. However, the behaviour and process segments are indeed segments where regulatory changes would be introduced. Greater emphasis is on behaviour aspects, as the two of the four findings are of mixed nature (related to both behaviour and process).

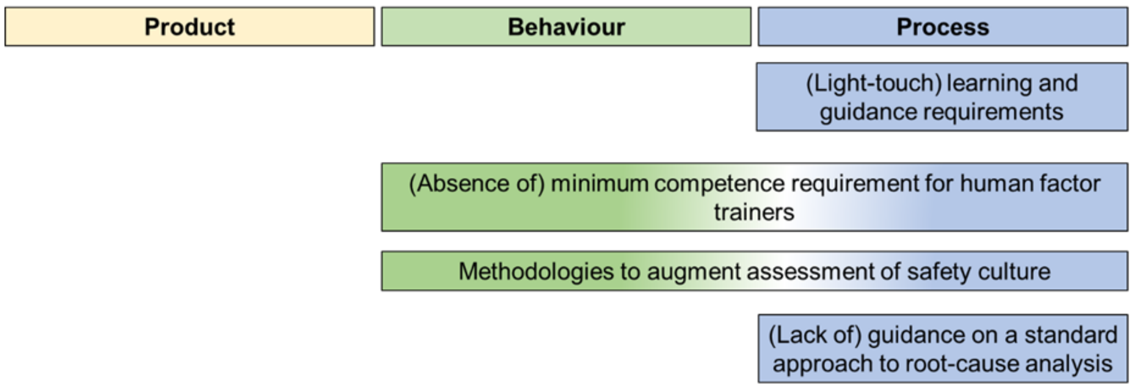

Figure 3.2. Mapping of the findings against the Product-Behaviour-Process (PBP) model (Purton *et al.* 2014) in relation to regulatory interventions.

3.6 Conclusions

The review of aviation safety regulations has revealed the following:

- A solid architecture of regulatory requirements is used by states to base their aviation regulatory frameworks.
- States have developed regulations, standards and practices in support of a common approach to aviation safety oversight. These enable organisations to develop a procedural approach to regulatory compliance in concert with safe operations.
- Regulatory stakeholders are aware of the tasks to be pursued so that current levels of safety are sustained and improved.
- Using safety intelligence derived from an efficient occurrence reporting system is an efficacious means of proactively identifying latent hazards and risks in potentially under-performing areas. A mechanism to be applied in Europe in support of achieving satisfactory safety levels is performance-based oversight, allowing better safety oversight upon aviation segments not performing well.
- Regulations encourage the proactive use of information in respect of lessons available from various sources. In addition to published accident and incident reports, internal data from reporting support mandatory continuation training for staff within AMOs and CAMOs.
- Examination of the primary enabling legislative requirements highlights underperforming areas within the enabling regulatory content. This could be used as input to EASA regulatory rule-making development groups tasked with the improvement of EU Regulation 1321/2014 (1321/2014) learning capability.

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Author's declaration regarding consequential impact of superseded publications.

1. The status of the publication's reference ICAO Annex 19 is recorded as effective 2013. However, the intervening (July 2016) and the current issue effective date is November 2019. An analysis of the amending revision reveals that the changes as defined by ICAO;

"*Further developments of safety management provisions and extensions of safety management systems (SMS) provisions to organisations responsible for the type design and/or manufacture of engines and propellers*", has no impact on the aviation activities featured in this document. The first amendment to Annex 19 adopted on 2 March 2016 (Effective 07 November 2019) completes the second phase and is based on existing principles with some restructuring intended to facilitate effective implementation.

2. The status of the publication's reference ICAO Doc 9859 is recorded as effective 2013. However, the current issue effective date is 2018. An analysis of the amending revision reveals that the changes as defined by ICAO;

To address the changes introduced by Annex 19, amendment 1 adopted on 2 March 2016 and to reflect the knowledge and experience gained since the last revision".

These changes have no impact on the aviation activities featured in this document.

Concluding statement

This chapter offered a practical insight for safety practitioners illuminating legislative gaps that if addressed could improve LFI in the subject industry segment. Chapter 4 now recounts the process of collection and analysis of data harvested from a group of industry participants. The study results reveal reported factors that enable and impede learning from incidents within the featured organisations.

Preamble and Statement of Author's Contribution Chapter 4

Chapter 4 details the development of a semi-structured interview template, the collection of data and resulting thematic analysis collected from a cohort of 34 industry participants. The results of the study could be applied in support of a working group to examine, strengthen and consistently apply learning from incidents (LFI) in the aviation industry. Author Contributions: Conceptualization, J.C. and K.I.K.; methodology, J.C.; formal analysis, J.C.; investigation, J.C.; validation, J.C and K.I.K.; data curation, J.C.; writing—original draft preparation, J.C. and K.I.K.; writing—review and editing, J.C. and KK. Both authors have read and agreed to the published version of the study.

Chapter 4. Learning from Incidents: A Qualitative Study in the Continuing Airworthiness Sector

Abstract.

Learning from incidents (LFI) is a useful approach when examining past events and developing measures to prevent ensuing recurrence. Although the reporting of incidents in the aircraft maintenance and continuing airworthiness domain is well appointed, it is often unclear how the maximum effect of safety data can be efficaciously applied in support of LFI in the area. From semi-structured interviews, with thirty-four participants, the gathered data were thematically analyzed with the support of NVivo software. This study establishes a relationship between an incident in its lifecycle and the learning process. The main aim of this work is to elucidate factors that enable LFI. The analysis of the data revealed, for example, the benefits of a just culture and the use of formal continuation training programs in this respect. Moreover, it identified limitations inherent in current processes such as poor event causation and poorly designed learning syllabi. Additionally, aspects such as a lack of regulatory requirements for competence in the areas of learning for managers and accountable persons currently exist. This thematic analysis could be used in support of organizations examining their own processes for learning from incidents. Additionally, it can support the development of terms of reference for a continuing airworthiness regulatory working group to examine, strengthen and better apply LFI in the aviation industry.

4.1 Introduction

If it were possible for all organizations to learn effective lessons from the past, the effects of future unwelcome events might be limited (Drupsteen and Hasle 2014). Aviation safety depends to a large extent on the efficacious efforts of all involved in the system (Chang and Wang 2010). Research has acknowledged the importance of event information when it comes to learning and preventing recurrence (Silva *et al.* 2017). Thankfully, major events such as accidents are becoming less frequent and generate less points for learning (Akselsson *et al.* 2012). In contrast, there are numerous incidents with less severe consequences and if appropriately considered, these could offer an earlier insight into the circumstances that enable unwelcome events. Predefined and relevant information harvested from incident reporting systems is a major element of learning and preserving acceptable levels of safety. Hobbs (2002) highlights the importance of aircraft maintenance staff being aware of the cumulative effect of "*seemingly insignificant*" incidents as this amplifies the need to be proactive when it comes to learning from incidents. This research undertook a qualitative examination of staff involved in aircraft maintenance and continuing airworthiness operations in order to identify factors that could augment learning from incidents within this industry sector.

In the areas of continuing airworthiness and aircraft maintenance, safety management systems include incident and occurrence reporting (1321/2014) as an obligation. It is common for incidents to be discovered within organizations and reported with the assistance of such "*systems of systems*" (Harvey and Stanton 2014). On an operational level, initial training on human factors and company procedures is intended to specify and re-affirm the category and type of occurrence and incident that should be reported. Recent developments in European Union (EU) regulations (376/2014) empower voluntary and confidential reporting and are independent of all other individual obligations. Detecting and identifying hazards highlighted through incident reporting systems is also recommended by the International Civil Aviation Organization (ICAO) standards and recommended practices as an effective means of augmenting levels of safety. However, Gerede (2015) strongly suggests that a failure to foster a just culture is considered to have a negative impact upon effective data collection (reporting), organizational learning and the subsequent ability to learn from incidents.

Drupsteen and Wybo (2015) reaffirm organizations use experience gained from past events in order to improve safety. Effective learning can be considered as a successful translation of safety information into knowledge. Utilizing information from events with learning potential can actively improve the operating environment and help prevent recurrence. Learning in this context can often be experienced as modifying or implementing new knowledge where cultural, technical or procedural elements are integrated. Therefore, when learning is transformed into measures to prevent re-occurrence, an organization often has a reasonable means of mitigating future similar events. Argyris and Schön (1996) highlight the importance of learning to detect and address effective responses to errors. Their "*theory in action*" concept is the focal point for this determination. The first of its two components, "theory in use" is one that guides a person's behavior. It is often 'tacit' and is how people behave routinely. Very often these observed 'habits' are unknown to the specimen. The second element is known as "*espoused theory*", namely what people say or think they do. Drupsteen and Guldenmund

(2014) mention that espoused theory comprises of "*the words we use to convey what we do, or what we like others to think we do*".

However, it is important to re-affirm the linkages that exist between individuals and organizational learning. The introduction of safety management systems (SMS) has initiated a shift in how organizational errors are viewed. Firstly, equipment has become increasingly more reliable, but the human form has not displayed the same response. In the second instance, the impact of complexities associated with an increasing cognitive load for staff is just beginning to be realized. The existence of a potential for blaming an individual is now being aligned with organizational responsibilities. Prior to this, event causation was often misrepresented or even over quantified the human input as organizational factors were not always considered. They offer an insight into the connection between individual actions and organizational initiatives designed to secure the best safety outcomes. Fogarty *et al.* (1999) also recognize the role that both individual factors have on human error and the inputs both can have on preventing recurrence.

Doc 9859 ICAO (2013b) defines a template for aviation operators and regulators to support the application of a variety of proactive, predictive and reactive oversight methodologies. In addition to routine monitoring schemes, voluntary and mandatory reporting, post incident follow-up, there are also regular safety oversight audits. These audits and inspections often set out to establish if there is a difference between espoused theory and the theory in use (e.g., is the task being correctly performed in accordance with the documented procedure/work instruction or is there a deviation from approved data and practice?). However, Drupsteen and Guldenmund (2014) caution auditors not to "*focus too much on the documentation of procedures*" alone. In such cases, the oversight audit may be ineffective because of its sole focus on espoused theories of the organization only and not the theory-in-use. These authors translate this idea of poor focus on theory in action, into a valid learning component arising from incidents. They also highlight the 'espoused' aspect where those attempting to learn from incidents often fail to experience the desired learning because outcomes are not fully aligned with the practical objectives of a learning from incidents (LFI) initiative. For learning to be most effective, espoused theory and theory in use should be reasonably well aligned. Ward *et al.* (2010) propose it is necessary to further develop an operational model that can account for "*what is meant to happen and what actually happens*".

Continuing airworthiness and aircraft maintenance and activities performed in EU member states are subjected to rules that mandate reporting of defined issues.

Repositories of reported data tend to be populated by sources that are predominantly the subject of mandatory reporting requirements. Conventional safety oversight models also only verify the presence of reporting media and repositories in this segment of the industry. Jacobsson *et al.* (2012) avow the degree of interest invested in learning from incidents but question its efficiency in some organizations. Although unwelcome events are less prevalent, less severe events still provide learning opportunities. There is often only a primary focus for organizations upon reporting in line with each state's own reporting obligations. Unfortunately, a narrow focus on this single element of an incident in its lifecycle can negate the potential benefits of learning from incidents at an organizational level. The absence of clearly defined competency requirements (1321/2014) that support a pedagogy for learning from incidents for continuing airworthiness staff could also be considered an impediment to effective learning in the domain.

The featured industry sector is regulated by the application and upkeep of numerous requirements in the jurisdictions of operation. In general, a costly regulatory overhead tends to be carried by regulating states and operators to support safe and viable activity. However, a growing tendency to increase regulatory requirements in pursuance of safer activity across the segments may not always offer the same returns as previously realized by states. Brunel (1841) (p.45) suggests, "*…it is impossible to make men perfect: the men will always remain the same as they are now and no legislation will make him have more presence of mind…*". Furniss *et al.* (2016) reviewed the Hollnagel (2004) Functional Resonance Analysis Method (FRAM) which explores how functional variability resonates within systems, i.e., how well comprising elements function in a system. They also consider how FRAM can be modified to support complex socio technical system improvements. Perhaps as the paradigm supporting the linearity of regulatory oversight shifts, proactive regulatory inputs will also influence more effective safety outputs as intricacy increases.

4.1.1 Systematic Literature Review

The primary reason for conducting a systematic review was to examine how learning from incidents occurs in aircraft maintenance and continuing airworthiness management. Other sectors and the issues impacting learning in these areas were also considered. The literature review sets out to establish factors that contribute to or potentially constrain learning from incidents in the subject domain. Applying a qualitative research approach is advantageous as it can provide a deeper contextual understanding of the literature and can assist with better research integration. The application of rigor and comprehensiveness can assist with advancing knowledge and identifying research gaps and aspects for further research in this area. Okoli and Schabram (2010) suggest "*a dedicated methodological approach is necessary in any kind of literature review*". A preliminary search of literature highlighted a scarcity of best-practice guidelines for conducting systematic literature reviews in this area.

Qualitative research involves handling considerable volumes of data and a degree of discipline is required so that search results, decisions regarding subject inclusions and exclusions are recorded and references are well managed. Endnote was used in support of the literature review during this research. An electronic database is useful for supporting a search strategy, arranging publications and storing references (Houghton *et al.* 2017). The qualitative data analysis software NVivo (NVivo 12, QSR International, Melbourne, Australia) was used to augment the data management, storage and analysis associated with the literature review. NVivo possesses many functions, such as facilitating the synthesis of a review (Bandara *et al.* 2015). A systematic search of in excess of 1000 publications was performed in the following databases: Web of Science, Scopus, IEEE Xplore, ProQuest and EBSCO. The following predefined search terms were applied: "*learning from incidents*", "*learning from experience*", "*aircraft maintenance*", "*aircraft management*" and "*safety management systems*". A practical screening of title and abstract was applied to each manuscript using predefined terms (e.g., subject, setting, publication, year). This part of the process had to be broad enough to create a sufficient number of applicable publications but also had to be practically manageable. The following criteria were implemented for the practical screening of the source bibliographic details, title and abstract:

- Subject—Related to learning from incidents and past experiences.
- Setting—Any high reliability industry or sector where learning from incidents is critical.
- Publication—Journal or peer-reviewed conference proceedings.
- Date range—published post 1992. The year 1992 was the starting point for the screening process, since at the time of planning the research project, 25 years was considered to be a reasonable timespan to include material pertaining to learning from incidents.

The output of the practical screen step produced a list of publications denoted as the screened set of publications. An Endnote library was then created to store and manage the full text of the retrieved publications. The next step involved filtering the publications into primary and secondary publication subsets using only primary research manuscripts in the next phase. Applying a set of criteria helps to reduce any researcher bias in the screening system. A set of inclusion and exclusion criteria (Gough 2017) was developed in accordance with the guidelines included in Meline (2006) and Wienen *et al.* (2017), listed in Table 4.1. Two researchers were involved in the screening process.

Table 4.1. Inclusion and exclusion criteria used for the filtering of the subset of primary publications.

Included	Excluded
Research studies	Literature reviews
Qualitative and mixed methods	Quantitative methods
Perceptions and experiences	Focused on decision-making and legislative requirements
Reference to just culture	
High reliability settings	
Published post 1992	
Peer reviewed publications	
Industry based settings	
Original studies	

The final set of 18 papers was imported into NVivo and the following analysis approach, as defined by Bandara *et al.* (2015), was used for the selection of the codification themes:

- Deductive - themes reported on are predetermined to some extent. In this case, these predetermined themes were the output of a focus group process.
- Inductive - themes reported are derived from analysis of the literature.

NVivo is limited in terms of providing thematic classifications based on the occurrence of key words but can assist with identifying relationships between words and phrases amongst publications. It also provided thematic classifications of data based on the occurrence of key words and phrases. The coding process consisted of selecting relevant passages of text that were captured in one or several of the framework nodes. Maykut and Morehouse (1994) defines a propositional statement as "*a statement of fact the researcher tentatively proposes, based on the data*". Memos were used to draft these summary statements which formed part of the literature review. Central to the idea of learning is how an incident is generally moderated during its useful existence. Section 4.1.2 documents this approach.

4.1.2 The Notion of a Generic Incident Lifecycle

Figure 1 illustrates how an incident tends to be managed through its quiddity. This view is one possible way of representing the elements comprising a lifecycle view. Cooke and Rohleder (2006) suggest it should also be evident that an incident system will operate most effectively when a safety management system has already been put in place and avoidable risks are addressed. They propose an effective system that addresses: identification and response, reporting, investigation, identifying causal structure, making recommendations, communicating and recalling incident learning, and implementing corrective actions. Drupsteen *et al.* (2013) also consider an incident from a learning perspective in its cycle. Their main constituents are investigating and analyzing incidents, planning interventions, intervening and evaluating (each of these four stages are further sub-divided into eleven sub-components). Continuing airworthiness-related incidents are notified by way of a formal mechanism of reporting. During the data gathering phase of this research, the steps outlined in Figure 4.1 were found to be dictated by regulatory requirements (376/2014 , 1321/2014). Once the incident enters its lifecycle, it ideally transverses a process that transforms the information gathered into knowledge. Figure 4.1 and the contiguous paragraph offer an overview of how the capture and processing of the incident information occurs in practice.

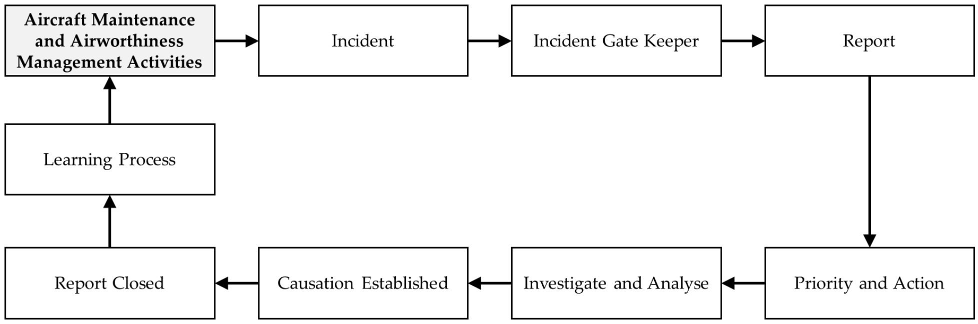

Figure 4.1. An example of an aviation incident lifecycle within the continuing airworthiness and aircraft maintenance sector.

Continuing airworthiness-related serious incidents are rare but often due to environmental, cognitive and mechanical demands, reportable and unreportable events do occur. All organizations in the industry segment subscribe to a reporting system and reports can be made electronically or in paper form in smaller organizations. The main underpinning regulation in Europe, EU Regulation (2018/1139), refers to a management system and mandates an organization to implement and maintain such a system to ensure compliance with these essential requirements. In practice, although a reporter can report events directly to an aviation authority, all organizations are required to have an internal reporting system also. A focal point/gate keeper will process these reports either internally and/or inform third party stakeholders such as aviation authority or aircraft manufacturer as required by procedure. Depending on the event, technical management may determine there are immediate actions required to recover a situation or restore serviceability. While a small number of scenarios will require an event to be investigated fully before an aircraft returns to service, many incidents are investigated post event. As soon as causation is established, if accepted by the relevant technical function, the report is closed. This management system is strongly influenced by regulatory requirements and procedural form and is a pre-eminent influence on how an incident and its actors behave from the time a report is made to the time its impact has been terminated. One of the limitations inherent in this cycle is that lessons tend to be delivered at a later point in time mostly through the medium of recurrent training programs such as continuation and human factors training. Therefore, there is often a hiatus in the feedback cycle. However, the effectiveness of the process and the perceived contribution to learning are not fully reflected in this view.

4.1.3 A Potential Learning Cycle Emerges

According to Lindberg *et al.* (2010), in order to prevent accidents, it is essential to learn from previous accidents and incidents. Lukic *et al.* (2012) suggest that in order to increase the effectiveness of learning from incidents, it is necessary to understand who should be included in the learning process. In Figure 4.2, the incident lifecycle is aligned with the learning process in order to highlight where potential improvements might be made. As the incident is managed and causation is established, there are potential avenues open for learning. The ultimate desired outcome is that adequate measures are put in place to prevent a recurrence of the event. However, the lessons available in a potential learning product are not always used to best effect when considering the Figure 4.1 process. Drupsteen *et al.* (2013) state that "*many incidents occur because organizations fail to learn from past lessons*", because the traditional approach often stops short of preventing future incidents. Their research examines: investigating and analyzing incidents, planning and prevention, intervening and evaluating steps in a learning process. Ward *et al.* (2010) found that the resulting relationship between the individuals and the systems have a direct impact upon the system and prevailing environment. Silva *et al.* (2017) examined how organizations use accident information to reduce the occurrence of unwelcome events. Drupsteen and Wybo (2015) found that hindsight can determine if an organization did learn from an event but there are no models to assist with gauging the "propensity" of an organization to learn. Drupsteen and Hasle (2014) suggest that learning can be improved if limiting factors are addressed.

The proposed enhancement (shown in Figure 4.2) to the generic lifecycle in the 'traditional' approach represents a novel view and brings the learning product into focus. This figure highlights the benefits of ensuring the feedback loop of an incident is centered on the learning product. Treating its development as an iterative process ensures all steps in the cycle are included and where deficiencies are noted, they can be identified and communicated during the iterations. This can assist with delivery of timely and sustainable learning and help prevent an inability to think, talk and see what actions are proper in specific situations (Steiner 1998). According to Drupsteen *et al.* (2013), it is necessary to gain an insight into the steps of the process to identify factors that hinder learning in order to make improvements. The research suggests an emphasis on accessible, timely and appropriate learning content could provide all stakeholders in the process with better value for their efforts. Perhaps one reason that the customary incident lifecycle and its limitations prevail is related to management theory. While innovators like Taylor (1911) are responsible for advances in management, such theories have not always fully considered safety and learning. The early 1900s witnessed a time when it was necessary to inaugurate efficiencies in production by initially decomposing tasks in order to introduce linear efficiencies. The limitations experienced in incident learning processes today may relate to this circumscribed tradition.

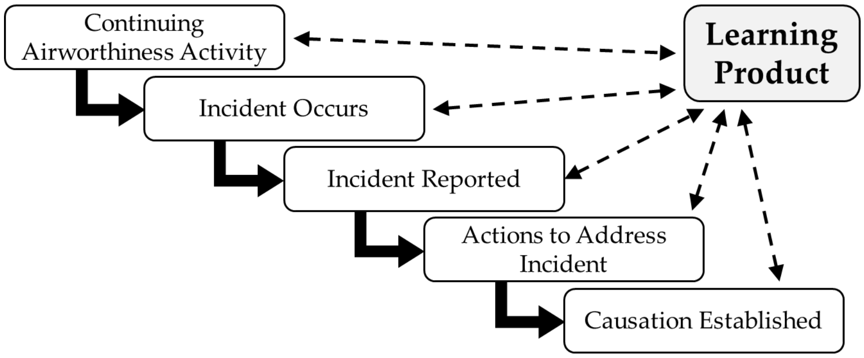

Figure 4.2. Incident learning product and process (broken line denotes iterative learning feedback).

4.2 Materials and Methods

4.2.1. Philosophical Underpinnings

The fields of science and philosophy consider ontology and epistemology in terms of What is the nature of reality? and How is human knowledge constructed? The ascendant ideologies of positivism and interpretivism can be applied in support of these philosophical differences (Weber 2004, Oates 2006). Hirschheim (1985) puts forward the aim of positivism to, "*seek to explain and predict what happens in the social world by searching for irregularities and causal relationships between its constituent elements*". In contrast to this stance, Schwandt (1994) suggests the aim of interpretivism is to gain understanding. Interpretive research seeks to develop a richer understanding of the complex world of lived experience from the point of view of those who live in it. "*This goal is variously spoken of as an abiding concern for the life world, for the emic point of view, for understanding meaning, for grasping the actor's definition of a situation, for verstehen"* (Schwandt 1994) (p.118).

The intent of this qualitative study was to understand how various situations impact on learning from incidents in the aircraft maintenance and continuing airworthiness management domain by interacting with the participants on a social plane. Thus, in order to gain an empathetic understanding of the participants and their actions, the pursuit of "*verstehen*" considers adopting an interpretive paragon as an approach. This approach is not initiated with the aid of a hypothesis intended for testing but rather using a lodestar that guides the researcher to a point of discovery supported with an inductive modus operandi. The study is unwavering in its support for the view that (individual and combined) qualitative and quantitative approaches possess equal value in terms of their investigative potential in this area of focus. In summary, the project employs a qualitative research methodology in an effort to generate 'rich' findings in support of gaining a good understanding of the learning environment in the featured domain. According to Maykut and Morehouse (1994), the purpose of qualitative research is to discover the inner world of perceptions and meaning making in order to gain an understanding to describe and explain certain social phenomenon from participants' perspectives. In order to accomplish this, focus group activity was managed concurrently with the literature review. These activities cumulatively generated five themes which were used as the basis for a semi-structured interview template. The project employed a qualitative research methodology in an effort to generate 'rich' findings in support of gaining a good understanding of the learning environment in the featured domain. The outcome of a qualitative research initiative was contextual findings as opposed to broad generalizations.

4.2.2 Focus Group

According to Kitzinger (1994), "*focus groups are group discussions organized to explore a specific set of issues such as people's views and experiences…*". The idea of conducting group interviews is not a new one. Bogardus (1926) is an early example of a reference to utilizing the group interview. Frey and Fontana (1991) suggest that group interviews can be formally structured for a specific purpose or can be performed in a more informal setting where a researcher can "*stimulate a group discussion*". Specific examples in the literature of focus groups being developed systematically within the area of aircraft maintenance and management are scarce. Frey and Fontana (1991) state that although group interviews have implicitly informed research, often they are not formally acknowledged as part of the process. Powell and Single (1996) remind us that when recruiting focus group participants, one must be mindful of systemic biases. Averting this was ensured by being careful to enlist the participants from different organizations and different positions of responsibility. Three sessions comprising of three industry professionals within each group were successfully moderated by the researcher. During the three phases of working with the focus group, statements and terms were recorded as dialogue amongst the members and observed. The second meeting of the focus group developed four codes (safety, regulatory compliance, root cause, reporting) that had emerged from the group's earlier outputs. These four codes were further distilled during the focus group activity and were consolidated into two themes (reporting, root cause) that were to eventually form part of the piloted semi-structured interview instrument.

Reporting and root-cause themes were the result of the draft consolidation of the comments and emerging codes. In concert with the focus group activities, a literature review was performed by the researchers and this generated three further themes as reflected in Table 4.2.

Table 4.2. Codification themes used in the NVivo analysis of the final set of publications.

Codification Theme	Description	Origin
Root Cause	Reason to establish causation	Focus Group
Reporting	Value of reporting to learning from incidents	Focus Group
Learning from Incidents	Outcomes of learning from incidents	Literature Analysis
Just culture	Impact of just culture on learning from incidents	Literature Analysis
Precursors	Contribution of precursors to learning from incidents	Literature Analysis

The resulting draft semi-structured template containing the five themes was scrutinized by the focus group. The constituent questions relating to each theme and the running order of the document was subject to many minor changes during the individual piloting of the instrument with the three group members.

4.2.3 Data Collection

Data were gathered from seven organizations using a semi-structured interview template. The participating organizations were involved in aircraft maintenance and continuing airworthiness activities. Building trust and commitment, as proffered by Chatzi (2019) and Chatzi *et al.* (2019) was deemed to be a necessary tenet of a successful data collection exercise. Managing the interview process with the support of senior staff complimented visible top-down support for the research and ensured there would be no confusion regarding access to what some organizations often classify as sensitive commercial data.

The aim was to explore how learning from incidents occurs and what can constrain learning in the area of focus. The pilot phase ensured the desired outcome of the main data collection phase would be congruent with the aims of the study. The interviews were recorded, transcribed and participants could not be identified from the recordings or transcripts. Full ethical approval for the data gathering was granted by the University.

4.2.3.1 Instrument

Data were collected using semi-structured interviews, lasting on average sixty minutes. The 'aide memoir' was arranged so that participants could offer a flexible response and any emerging themes could be identified. The semi-structured approach facilitated emphasis being placed upon any points that warranted further focus or examination by the researchers. An example of the interview template is included in figure 4.4. Interviewees were asked to give an example of a recent incident they were familiar with. The structure of the template, (a) probed process around reporting and (b) elicited the participants perception of learning from incidents within their organizations. Following on from the initial contact on reporting, the participants discussed just culture, learning, root-cause and incident precursors during their individual engagements with the researchers.

4.2.3.2 Participants

The "*key issue in selecting and making decisions about the appropriate unit of analysis is to decide what it is you want to be able to say something about at the end of the study*" (Patton 1990) (p.168). The objective of this study was to investigate individuals' perceptions of how learning from incidents takes place and the obstacles present in the maintenance and continuing airworthiness management domain of the aviation industry segment. There were thirty-four (34) participants in total, as presented in Table 4.3.

Table 4.3. Participants in the study (n = 34).

Participant Roles	Number
Category B1 Engineer	4
Supervisor	3
Category A Mechanic	3
Quality Assurance Engineer	3
Category B2 Engineer	2
Shift Controller	2
Contract Composite Inspector	1
Inspector	1
Aeronautical Engineer	1
Category B1/B2 Engineer	1
Maintenance Manager	1
Technical Safety Manager	1
Technical Services Manager	1
Line Maintenance Manager	1
Deputy Quality Manager	1
Maintenance Control Manager	1
Maintenance Planner	1
Maintenance Safety Officer	1
Apprentice Technician	1

Each of the organizations maintained between 6 and 300 aircraft at the time of the study. While traditional reporting and learning themes were evident outputs from the focus group meetings, it was decided that the data would be collected through one-to-one semi-structured interviews. Semi-structured interviews permitted the researchers to get a deeper understanding of complex organizational and social interactions and at the same time follow a construct. The participating organizations were selected based upon them being accredited to perform aircraft maintenance and continuing airworthiness activities since the inception of EU regulation 1321/2014 (1321/2014). Within this domain, there are categories of staff that are required to be aware of incident reporting and make a report as necessary (e.g., technical managers, certifying staff, quality assurance staff, stores personnel, technical services). Each organization is required under legislation to employ a satisfactory level of staff regardless of their aviation activities. As a minimum, at least one of each of these roles was represented in the study. It was ensured that at least one staff member from each discipline was included in the study and had made a report in the previous twelve months. As certifying staff, technical managers and quality assurance staff are by virtue of their position active reporters (due to their exposure to active operations), staff in these disciplines were well represented in the study's cohort. Participation in the study was on a voluntary basis and all who participated were acquainted with the project prior to performing the interviews. All participants signed consent forms.

4.2.4 Data Analysis

Thematic analysis was the method chosen to support the analysis of the study's data. The Braun and Clarke (2006) six-step proposition, which consists of eight discreet cycles, in conjunction with the QDAtraining (2013) material, formed the basis of the analysis technique. A practical iterative approach was adopted throughout the analysis where the data were formally arranged into discrete phases. The eight individual stages of analysis distributed over the six phases were designed to support a robust and rigorous analysis of the data. Table 4.5 below illustrates the stages and processes outlined and performed in NVivo and links this to the practical guidelines set out in Braun and Clarke (2006). Their six-step approach that supports the application of thematic analysis is shown in column one and the corresponding application in NVivo is shown in column two. The third column features the strategic elements of coding as the researcher moved from the initial participant-led descriptive coding, to the secondary coding which was more interpretative in nature indicating this phase of coding was both researcher- and participant-led. The final abstraction to themes was researcher informed only. This phase was designed to allow the researchers to engage the participant in direct dialogue with a wider arena such as literature and policy or strategy for example. The fourth and final column illustrates the more iterative nature of the coding, analysis and reporting of proceedings that terminate in a conclusion.

Phase 1 activity involves familiarizing oneself with the transcribed data. In this first phase, the data were loaded into NVivo. It was checked and re-read several times to ensure accuracy of the uploaded transcripts. At the end of the phase activity, initial codes were noted down and retained.

Generating initial codes (open coding: phase 2)—According to Lincoln and Guba (1985) (p.345), a data unit can be defined as the "*smallest piece of information about something that can stand by itself, that is, it must be interpretable in the absence of any additional information other than a broad understanding of the context in which the inquiry is carried out*". The open coding is intended to systemically organize the data and uncover the essential ideas found in the data (Baskerville and Pries-Heje 2004). Each discrete unit of data is labelled in line with the phenomenon it represents. The second phase required broad participant-driven open coding of the interview transcripts recorded during the data gathering step of the research study. Features of interest were coded in a systematic way across the complete dataset where data relevant to each code were collected. Clear labels were allocated to these codes and definitions to serve as rules for inclusion (Maykut and Morehouse 1994).

A set of provisional categories was generated for the segmented data to be coded to. These categories were descriptions of concepts and themes in broad terms. They took two forms: researcher-driven and participant-driven. The former was derived from a theoretical framework underpinning the study and the latter from the knowledge gained of the participants' language and customs. Hammersley and Atkinson (2007) (p.153) consider the importance of participant-driven categories: "*the actual words people use can be of considerable analytic importance as the 'situated vocabularies' employed provide valuable information about the way in which members of a particular culture organize their perceptions of the world, and so engage in the social construction of reality*".

Searching for themes—In phase 3, codes from phase 2 were collated into categories of codes by structuring all the data relevant to each potential category into a framework that could be used in support of further analysis. This phase also included distilling, re-labelling and merging common codes that were generated in phase 3 to ensure the labels and definitions for inclusion were an accurate reflection of the coded content. These first-round categories are best described as broad descriptions of concepts and themes. During the analytical process they underwent content and definition change and the existence of the two forms of category provides an important means of traversing between "natural" and "theoretical" discourses. Araujo (1995) (p.68) suggests that "*codes should be viewed in two ways: as part of the analyst's wider theoretical framework and as grounded in the data.; the process of coding data should be regarded as an important intermediary step in translating social actors' frames of meaning into the frame of theoretical discourse;*

coding frames therefore, mediate between the 'natural' everyday discourse and the theoretical discourses in social science".

Reviewing themes (coding on) in phase 4 required further decomposition of the study units of data identified in phase 1. This activity was intended to support a greater understanding of the highly qualitative elements and gain a deeper appreciation of the meanings contained within. It should be noted that not every task could be further broken down and this meant that the activity was performed only as required. Restructured codes were broken down into further sub-codes in order to augment a greater understanding of the meanings embedded within them. These distinctive aspects included communication with management, discovering latent issues, just culture, learning lessons, reporting, root causes and story of an incident.

Defining and naming themes in phase 5 of the data analysis was concerned with analyzing the tentative categories identified in phase 2 for their properties and characteristics. This is a pre-cursor to drafting a propositional statement for each category. Developing analytical memos moves the process beyond identification and description of broad categories to a position of analyzing and fusing meanings in the data under each category. This progressed to drafting a statement that aspires to illustrate the concerted meaning of the segments of data coded to each category. Maykut and Morehouse (1994) (p.140) defines a propositional statement as, "*a statement of fact the researcher tentatively proposes, based on data*". This phase in addition to further data analysis to refine the specifics for each theme, generated clear definitions and a name for each theme. It also involved data reduction by consolidating categories from all three cycles into a more abstract, philosophical and literature-based thematic framework and conceptually mapping and exploring their relationships with one another for reporting purposes.

Producing the report in phase 6 required analytical memos to be written against the higher-level themes to present an accurate summary of the content of each category and its codes and to also propose findings. The tasks associated with phase 6 included (i) generating analytical memos, (ii) testing and validating and (iii) synthesizing the memos coherently and cohesively and was performed simultaneously. Writing the analytical memos against the higher-level codes (i.e., learning from incidents, learning process and learning product) required an accurate summary of each category and its codes and findings against categories. These memos considered a few key areas:

- The content of the cluster of codes which were being reported on.

- Patterns where relevant.
- Considering background information noted against participants and examining any patterns relating to participants' profiles.
- Considering any relationship between codes and their importance in relation to the research questions.
- Noting any primary sources relating to the context of the relationship with the literature in addition to highlighting any gaps in the literature.

Testing, validating and revising analytical memos was performed in phase 7. The purpose of this was to provide a self-audit of the proposed findings by soliciting evidence in the data beyond just textual quotes in support of the recorded findings and to also expand on deeper meanings within the data. This required the data to be interrogated, not only relying on relationships across and between categories, but also a degree of cross tabulation with demographics, observations and the literature. The outcome of this phase was evidence-based findings as each proposed finding was validated by being rooted in the data themselves and was reliant on the creation of reports in support of substantiated findings.

The discipline of writing analytical memos was used during the data analysis process. Birks *et al.* (2008) believe "*memoing serves to assist the researcher in making conceptual leaps from raw data to those abstractions that explain research phenomena in the context of which it is examined*". In general, memos were employed at the "ideation" stage when the researcher was developing thought processes and early in the data capture phase. As decisions were made, the early processes and rationale for final analysis iterations were recorded using this medium. Memos were further employed to preserve an objective closeness to the harvested data and to maintain the context of each semi-structured interview at the participating individuals' level. Developing ideas, reasons for considering possible category relationships and connections was also possible through the application of the analytical memo process. The rigorous support memoing offered served to guide the analysis of the data through different levels of abstraction (Miles and Huberman 1994). The rule of this activity served to ensure a high degree of continuity between the outputs of ideation and the evolving interpretation that were honed through the researchers' articulation, exploration and their iterations of the data. Overall, this drew out the meanings in the data through the increased sensitivity the researchers were offered by applying the memoing process (Birks *et al.* 2008).

In phase 8, the analytical memos were synthesized into a coherent and cohesive report with the findings well supported. The final phase involved the assembly of the narrative with the data extracts while appreciating the product of this amalgam in the context of the related literature. The example features the finding, clear links to the interview data and literature and an explanatory narrative in the form of a memo. This finally resulted in the compilation of the report which contained the results and discussion elements of the body of work.

Table 4.4. Stages and Process Involved in Qualitative Analysis. Adapted from Braun and Clarke (2006) and QDAtraining (2013) material.

Analytical Process (Braun and Clarke, 2006) [47]	Practical application of Braun and Clarke in conjunction with NVivo	Strategic Objective	Iterative Process Throughout Analysis
1.Familiarizing yourself with the data	Phase 1. Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas. Import data into the NVivo data management tool		Assigning data to refined concepts to portray meaning
2. Generating initial codes	Phase 2. Open Coding: Coding interesting features of the data in a systematic fashion across the entire data set, collecting data relevant to each code	**Data Management** *(Open and hierarchal coding through NVIVO)*	
3. Searching for themes	Phase 3. Categorization of Codes: Collating codes into potential themes, gathering all data relevant to each potential theme		Refining and distilling more abstract concepts
4. Reviewing themes	Phase 4. Coding on: Checking if the themes work in relation to the coded extracts (level 1) and the entire data set (level 2), generating a thematic "map" of the analysis	**Descriptive Accounts** *(Reordering, 'coding on' and annotating through NVIVO)*	
5. Defining and naming themes	Phase 5. Data Reduction: On-going analysis to refine the specifics of each theme, and the overall story (storylines) the analysis tells, generating clear definitions and names for each theme		Assigning data to themes/concepts to portray meaning
6. Producing the report	Phase 6. Generating Analytical Memos. Phase 7. Testing and Validating. Phase 8. Synthesizing Analytical Memos. The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis [47,48]	**Explanatory Accounts** *(Extrapolating deeper meaning, drafting summary statements and analytical memos through NVIVO)*	Assigning meaning Generating themes and concepts

In summary, this study adopted an interpretative approach pivoting on the fact that it was of an exploratory nature. The study performed thirty-four interviews in eight aircraft maintenance and management organizations based in Ireland. An analysis of various potential research methods and means of data collection resulted in the following research design being implemented. A thematic analysis approach was employed as a research methodology:

- Unit of analysis is an individual;
- Semi-structured interview guide was constructed following a systematic analysis of literature and the use of a focus group;
- Data were collected through qualitative interviews;
- Thirty-four interviews were collected in locations endorsed by eight organizations;
- Qualitative analysis based on the guidelines from Braun and Clarke (2006) (thematic analysis) employing a six-phase approach was used in the study.

4.3. Results and Discussion

4.3.1 Framework

Figure 4.3 presents a framework that offers an insight into how the present study applied the research inputs and produced the results.

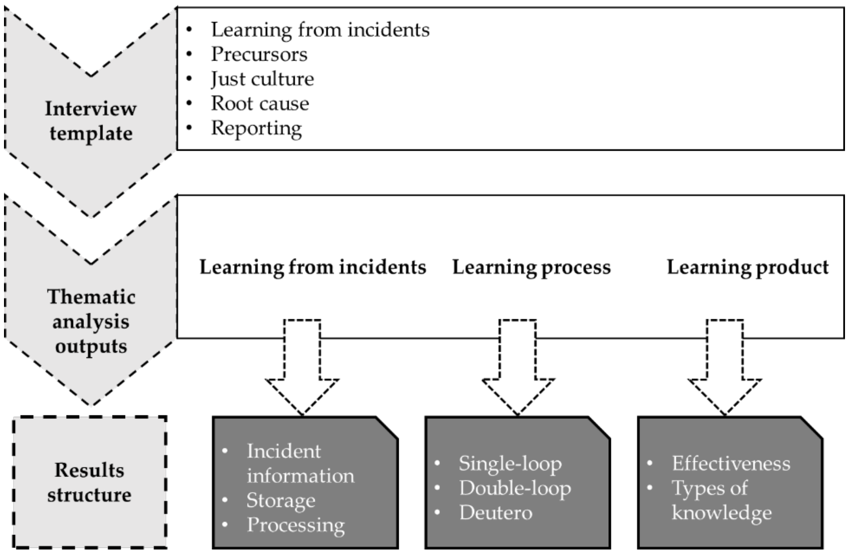

Figure 4.3. Research study framework.

The top layer reflects the five themes that formed the basis for the data gathering template. These themes were developed through an iterative process of conducting focus group sessions with two themes emerging, i.e., root cause and reporting. Concurrently, a systematic literature review was performed using NVivo software to assist the researchers manage over 1000 screened publications. Following a thematic analysis of the data, three main themes emerged from a final cache of 18 publications, i.e., learning from incidents, precursors and just culture. The five themes informed the structure of a data gathering instrument that supported 34 semi-structured interviews in the continuing airworthiness segment of the industry. Following transcription, the data were uploaded to NVivo where they were thematically analyzed using the Braun and Clarke (2006) framework. The outputs from the thematic analysis distilled the interview analysis into three main outputs, i.e., learning from incidents, learning process and learning product. The lower tier represents the elements the themes were comprised of and the findings are presented under these headings (Figure 4.3).

Table 4.5. Summary of results. [1] Learning from incidents (LFI) is a safety management activity with a desired outcome of preventing unwelcome event recurrence.[2] A learning process facilitates a change in knowledge and behavior intended to support LFI.[3] Safety related information arising from the LFI process.

Learning from incidents [1]	Learning process [2]	Learning product [3]
The decision to report an incident can be impacted by the perceived commercial pressure and the potential for embarrassment associated with making a mistake, amongst front line maintenance staff.	The release of a safe aviation product is the primary goal all operational maintenance and management staff espouse to.	In the organizations supporting the study, it was apparent that incidents are managed with the support of a consistent life-cycle methodology.
Identifying and understanding organizational behavioural and human factors are important elements affecting decisions to report.	Single-loop learning is a level of learning that can exist in a dynamic operational environment where a “find and fix” ethos exists.	Learning products that arise from the managed lifecycle of an incident are intended to impart sufficient learning to prevent recurrence or occurrence of same or similar events.
Inadequately resourced investigation and follow up of incidents does not support the determination of accurate event causation and measures to prevent similar incidents reoccurring.	The mandatory human factors continuation training program is considered by study participants to be an effective enabler of double-loop learning.	While aircraft manufacturers generally provide feedback on notified incidents, component manufacturers provide less feedback with little or no feedback arising from aviation authorities on submitted reports in the jurisdiction of the study.
The recognition of the extended impact of under-reporting on “levels of learning” is not always a priority in some organizations.	Evidence amongst study participants where a review of single and double-loop learning within organizations was not available during the study.	The cost of classroom delivered continuation training is a primary consideration for most organizations.
The absence of a potential learning product that results from effective reporting is an impediment when attempting to gauge the effectiveness of learning.	No formal requirement for competence in the areas of learning for managers and accountable persons exists in EU regulation 1321/2014.	Computer based training is an option that is under trial by some organizations but there are concerns amongst operational staff regarding its overall effectiveness in its current form.
Pressure to prematurely close incident reports does not promote thorough event causation and measures to prevent similar incidents reoccurring.	No competence requirements for staff involved in the development or delivery of formal human factors continuation training programs.	Just culture has a positive impact on reporting rates.
		Feedback to staff on incident causation factors from an information and learning perspective is important.
		Poorly designed continuation training syllabi do not support effective learning.
		Timely follow up to incident reports supports more effective learning outputs from the reporting process.

4.3.1.1. Learning from incidents—Acquiring, Processing and Storing data

Incident reporting is accepted as a worthwhile activity amongst those participating in the study. This is based on the collective notion that the initiative raises awareness of incidents and potential hazards and can therefore help prevent event recurrence. The authors recognize that awareness is an important component of learning from incidents. Situations do arise where due to lack of report data, it is questionable if all the necessary reports are being submitted as required. Amongst the constraints to making a report are perceived production pressures and the potential embarrassment that could arise from making a mistake and highlighting it (Hobbs 2003). There are just culture concerns amongst some staff because they do not always know what the impact for them personally will be if they submit an incident report (Chatzi 2019).

A dedicated focal point in organizations is essential for the systematic management of reported incidents. Where this discipline is applied, the process owner is responsible for highlighting reported issues and raising the necessary awareness amongst operational staff. Once an incident is acquired through the efforts of a reporting system, some form of processing and analysis is necessary. The availability of adequate resources for determining causation and implementing measures to prevent recurrence was identified as a primary point of concern. Perceived premature closure of reports was also highlighted amongst participants. There was a call for improved accountability and transparency on decisions relating to some closure actions. Respondents associate the practice of applying commercial key performance indicators to safety management as shallow efforts are sometimes made by organizations to expeditiously and prematurely close reports on occasion. Incident reporting and safety management initiatives have been in existence for some time. Large repositories of associated safety data are stored in many organizations. Although entities are mandated to inform key stakeholders, there is a strong opinion amongst some participants that the data repositories could be aggregated and put to better use in support of learning amongst all operators.

4.3.1.2. Learning Process—Single-loop, Double-loop and Deutero-Learning

The interview data confirms that safety is a primary underpinning value in the organizations that participated in the study. The release of a safe product, i.e., an aircraft or component, is a formative pursuit and measure of learning. In organizational environments where a "*find and fix*" ethos may prevail, single-loop learning (Argyris and Schön 1996) is evident in the examples presented. A desired outcome of double-loop learning (Argyris and Schön 1996) is often witnessed for example through the adjustment of environmental, behavioral and procedural norms. Instances of double-loop learning can be evident following unsuccessful attempts through single-loop learning where causation is then adequately understood and actioned. Continuation (mandatory in-service) training was considered by study participants as an effective mechanism that enables double-loop learning. During the study, it was apparent that single and double learning loops are recognized amongst many participants as having differing capabilities in terms of delivering an effective learning product. However, there was no evidence of formal reviews of single and double-loop learning being performed within the participants' organizations. Although deutero-learning (Bateson 1972) (Argyris and Schön 1996) may be considered as a natural extension of other levels of learning, the concept did not feature strongly amongst the participants. A review of the EU regulation 1321/2014 (1321/2014) implementing requirements confirms an absence of any mandatory requirement to review learning processes.

4.3.1.3. Learning Product—Effectiveness and Types of Knowledge

Continuation training is a mandated European requirement (1321/2014) for all aircraft maintenance and continuing airworthiness management organizations. It is a product as well as a medium for imparting learning from incidents and safety related hazards. It was identified during the study that the learning product is shared amongst staff through three primary means of distribution: formally delivered continuation training, tool-box talks and safety briefings and electronic, paper, notice board and 'read and sign' safety publications. The study suggests a learning product can arise as a result of an output from an incident lifecycle. Feedback from submitted occurrences to stakeholders varies from very good to poor. Cost is seen as a major consideration in some of the participating organizations when planning continuation training delivery. Although computer-based training is being considered in some companies as a viable option to class-room delivery, concerns are evident in respect of effectiveness of this medium in its current form. Bedwell and Salas (2010) suggest computer-based training (CBT) can be used as a methodology for providing, "*systematic, structured learning; a useful tool when properly designed*".

The perceived overburdening of operational staff with complex learning products and excessive cognitive loads was recorded as an impediment to learning during the study.

Participants suggested this can arise from poorly designed training syllabi delivered during periods of high operational activity.

Four knowledge types were identified and relate to: conceptual, dispositional, procedural and locative knowledge forms (Thorndike 1918). One of the key objectives of learning from incidents is to identify the type of knowledge needed to prevent an issue recurring. When a reportable issue, for example, is discovered, the submitted report will identify "*what*" happened. Subsequent follow up will set out to determine "*why*" the issue occurred. The guiding principles of "*how*" to perform the task or operation are often contained in procedures or data particular to the task. The information contained in procedures will enable a person to utilize other forms of knowledge. Prevailing safety culture within an organization will have an impact on learning from incidents. If a strong commercial/production culture exists, this may have an impact on, for example, the depth and breadth of learning from incidents within the company. Induction and initial training are important when accessing information for new staff. Accident data repositories contain well-documented human factor-related examples often relating to access to approved data and consequently resulting in potentially preventable incidents. Examining the limitations of each type of knowledge when continuation training programs are being developed was flagged as important by some participants. During the study, no discernible differences were recorded in how the types of knowledge were differentiated in participant organizations. A review of the EU 1321/2014 (1321/2014) human factors syllabus requirements did not highlight a need to appreciate or account for these human centered limitations when designing and delivering training lessons. Improved regulatory guidance on the design of effective human factor related material should therefore be developed. Information on how training should be structured in order to appreciate types of knowledge and capitalize on it as a minimum are required to ensure the most efficacious outcome from incident-related training.

4.4. Conclusions

An ameliorating feature of learning from incidents is the potential to effect sustainable improvements in aviation safety. A review of safety from the perspective of maintenance and continuing airworthiness staff is key to understanding the relationship between safety and the concept of learning from incidents (Lukic *et al.* 2012). From the study's qualitative data, we were able to identify how learning occurs in the airworthiness segment, and issues that support and constrain learning. Recurrent mandated training initiatives such as continuation training were found to be pivotal in enabling learning. Aspects such as prevailing culture and poor event causation were noted to have a negative impact on learning. Our proposed incident learning process (Figure 4.2) offers a panoramic of where potential learning opportunities and procedural improvements can arise within the lifecycle of an incident. This perspective could be applied in support of developing regulatory working group specifications and validating continuation training initiatives. In addition, it could also be used to develop a holistic review approach to learning from incidents within other organizations both in the aviation industry and outside. Two notable limitations to our research arise. First, the scarcity of prior studies capable of supporting the basis for the research was pronounced. However, prior studies in parallel domains were successfully leveraged in support of the literature review. Second, the study's population (n = 34) was relatively small. As the study participants were representative of all affected domain functions and a point of saturation was reached, it was deemed adequate. This research is capable of supporting other papers on additional benefits associated with learning from incidents (LFI). Notably, with the imminent implementation of a safety management (SMS) requirement for continuing airworthiness organizations, potential improvements to hazard identification arising from learning from incidents (LFI) could be highlighted.

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Institutional Review Board Statement: The study was conducted according to the Institutional guidelines and approved by the Institutional Ethics Committee of University of Limerick (Research Ethics Approval Number: 2015_12_06) dated 6 December 2015.
Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.
Data Availability Statement: The data presented in this study are available on request from the corresponding author.
Conflicts of Interest: The authors declare no conflict of interest.

Concluding statement

This chapter identified potential organizational and regulatory LFI short-comings evident in the participating organizations. Chapter 5 presents an analysis of a sample of 15 reported occurrences and aligns the output with a known learning taxonomy. A novel learning archetype with a focus on the 'learning product' is introduced.

Semi-structured interview template.

Code 1	Code 2	Previous positions	Years in previous positions
Position	Years in position	Qualification	Type of organisation

a. Reporting
- Could you describe an occurrence/incident that happened recently?
- How is a report made?
- Who decides what events to report?
- Where does the requirement to report come from?
- How is the importance of reporting highlighted in the organisation?
- What do you think the aim of reporting is?
- Have you received feedback from reports you have submitted?

b. Just culture
- Do you think there is a good safety culture in the organisation?
- Why is this?
- Is it easy to communicate with management on safety issues?
- Do you feel a just culture exists in the company? (Why is that?)
- How does just culture impact on reporting?

c. Learning
- How are lessons that arise from occurrence/incident reporting delivered to staff in your area?
- How is learning achieved? (What is the process?)
- What obstacles to learning from incidents have you experienced in your position?
- In your opinion, what conditions or developments could improve learning from incidents/occurrences in your organisation?

d. Root cause
- What is your opinion on efforts to establish a single root cause when an incident/occurrence is investigated?
- Is this approach always effective?
- What situations have you experienced where incident causes can be numerous and complex?

e. Occurrence/incident pre-cursors
- How important is it to identify and report events not required by the mandatory occurrence reporting (MOR) schemes? (Why is this?)
- Is the organisation's occurrence/ incident reporting system capable of managing reports other than MOR's?
- Is there a better way of gathering and using the potential information from non-mandatory events? (What would you suggest?)

Figure 4.4. Semi-structured interview template.

Preamble and Statement of Author's Contribution Chapter 5

Chapter 5 presents the results of the analysis of 15 selected incidents and maps the outputs against a recognized taxonomy. Additionally, the papers introduces a novel approach to learning from incidents that is learning product centric.

Author Contributions: Conceptualization, J.C. and K.I.K.; methodology, J.C.; formal analysis, J.C.; investigation, J.C.; validation, J.C and K.I.K.; data curation, J.C.; writing—original draft preparation, J.C. and K.I.K.; writing—review and editing, J.C. and K.I.K. All authors have read and agreed to the published version of the manuscript.

Chapter 5. Analysis of Continuing Airworthiness Occurrences under the Prism of a Learning Framework

Abstract.

In this research paper fifteen mandatory occurrence reports are analyzed. The purpose of this is to highlight the learning potential incidents such as these may possess for organizations involved in aircraft maintenance and continuing airworthiness management activities. The outputs from the mandatory occurrence reports are aligned in tabular form for ease of inclusion in human factors' continuation training material. A new incident learning archetype is also introduced, which intends to represent how reported incidents can be managed and translated into lessons in support of preventing event recurrence. This 'learning product' centric model visually articulates activities such as capturing the reported information, establishing causation and the iterative nature of developing a learning product.

Keywords: aircraft maintenance; airworthiness; learning from incidents; aviation safety; learning taxonomy

5.1 Introduction

Structured and continuous safety management actions, such as collection of data, analysis and intervention can be enabled with the support of the necessary safety intelligence. High quality maintenance and management tasks are some of the essential inputs for safe operations. Continuous information 'harvested' from incident reporting arising from these tasks, is another major part of learning and preserving acceptable levels of safety (Silva *et al.* 2017). Thankfully, serious incidents are becoming less frequent (Akselsson *et al.* 2012) but often because of environmental, cognitive and human centric demands, reportable and unreportable events do occur. The main underpinning aviation regulation in Europe, European Union (EU) regulation 2018/1139 (2018/1139) refers to "*management system*" and mandates an operator to implement and maintain a management system to ensure compliance with these essential requirements for safe operations; it also aims for continuous improvement of the safety system through learning from incidents.

In the area of continuing airworthiness, the fundamentals of management systems are also extended to incident and occurrence reporting through the implementing conduit of EU regulation 1321/2014 (1321/2014). It is common for incidents to be discovered within organizations and reported with the assistance of such 'systems of systems' (Stanton and Harvey 2017). On an operational level, initial human factors training, and company procedures are intended to specify and re-affirm the class and type of occurrence and incident that should be reported. Recent developments in Europe in the guise of EU regulation 376/2014 (376/2014) empower voluntary and confidential reporting and are independent of all other individual obligations. The paper recounts an analysis of 15 occurrences drawn from a repository of reportable incidents. Each incident was assessed, and the report data interpreted to support potential primary and secondary causation factors. To translate these learning points into tangible lessons, causation factors are harmonized with a taxonomy for learning. This taxonomy is based upon the Transport Canada 'Dirty Dozen' (Transport Canada 2003) human factors terms which feature common aviation human error preconditions. Additionally, a framework is presented in the paper to demonstrate how learning from incidents can be leveraged with best effect in the industry segment. Mandatory reportable incidents are notified through the formal mechanism of reporting. Once the incident enters its lifecycle, it ideally transverses a process that transforms the information gathered into knowledge. This knowledge is intended to assist with the prevention of similar future events.

5.2. Safety Reporting Background

5.2.1 International and European Regulatory Context

Safety information databases containing appropriate details of events with potential and latent ancillary contributors are available and can be considered with the assistance of continuous analysis. In the United States a combined effort by the aviation industry, organizations and individuals, known as the Aviation Safety Reporting System (ASRS) (FAA 2015) collect reports that are submitted on a voluntary basis. The outputs from this initiative set out to identify system deficiencies and raises correspondence directly with the responsible people. The intention is to affect learning and improvements that correlate with corrective actions that avert event recurrence.

On a wider scale through the diligent offices of the International Civil Aviation Organization (ICAO), standards and recommended practices that define contracting state reporting and analysis obligations, have been developed as a result of the collective efforts of participating states. For example, Annex 13 Aircraft Accident Investigation (ICAO 2010) to the Chicago Convention (ICAO 1944) defines the standards that require states to report accidents involving aircraft with a maximum take-off weight (MTOW) of 2250 kg and above. The document also contains details of reportable incidents (MTOW 5700 kg) that are considered important in terms of safety and accident prevention. An accident/incident data reporting system (ADREP) is operated and managed by ICAO. Safety data from (ICAO) member states are received, verified and retained in the ADREP system. The repository contains an aggregate of occurrences/incidents/accidents reported by the contracting states. The Accident/Incident Reporting Manual (ICAO 2014) document defines the report content, its composition and means of transmittal to ICAO. A common group of general codes known as a taxonomy is used to standardize the inputs for reporting. In an effort to improve harmonization and exchange of information, most European aviation competent authorities have already migrated to the ICAO common ADREP taxonomy.

The EU, in recognition of its duty of care to the travelling public acknowledges that it must continue to improve levels of aviation safety. Based on a global expectation (Boeing 2015) of the imminent increase in aviation activity, significant challenges are evident if EU is to only preserve current levels of safety. Presently, air passengers enjoy the benefits of a safe industry based on the technological advancements, recognition of human performance and limitations, compliance primarily with prescriptive regulations and the learning potential arising from past accidents and incidents. The EU regulation 376/2014 (376/2014) was developed to enable the collection, analysis, and follow-up of reportable incidents and occurrences. It mandates provisions for reporters to submit mandatory occurrence reports (MOR's) and voluntary occurrence reports (VOR's). There are discriminating conditions that must be met in order to determine which 'conduit' is required to report a hazard or incident. The regulation also defines reporting timelines for initial reporting (within 72 h of discovery) and for reporting to the competent authority (within a further 72 h). Organizations are also required to have a process in place to implement timely follow-up and notification of their analysis to their competent authority. In Europe, reporting entities are encouraged to submit reports through a reporting portal moderated by the European aviation safety agency (EASA). Civil aviation competent authorities have access to the portal and the incidents and accidents are categorized in accordance with a standard aviation data reporting program (ADREP) taxonomy. They are then uploaded to a European coordination for accident and incident reporting systems database (ECCAIRS). This multi-modal European transport database can facilitate the collection, analysis and sharing of transport safety data.

5.2.2 Learning from Incidents: Underpinning Theory

According to Leveson (2004), a holistic view of an organization's capability in terms of learning from incidents can be enhanced by shifting the focus from the individual to what is happening across the system. In the world of 'operational aviation' the concept of Safety Management Systems (SMS) has been for the most part successfully embraced and applied where mandated. Deming (2000) the respected purveyor of quality assurance methodologies asks the question, "*what is a system?*" He continues to answer, "*a system is a network of interdependent components that work together to try to accomplish the aim of the system*". This description of the system suggests that the process (in safety management parlance) is "*a network of interdependent components*". Safety management philosophy requires specific points to be formally addressed so that the safety management process of operational risk can be explicitly expressed and therefore effectively managed. One of these points is preventing the recurrence of incidents and occurrences through learning from past events to achieve an acceptable level of safety.

Today, in many jurisdictions it is a requirement for aircraft maintenance and continuing airworthiness management organizations to maintain an occurrence-reporting system. European regulatory requirements (376/2014) and organization procedures (1321/2014) normally require the event to be investigated, documented and the causal factors considered. Additionally, corrective and/or immediate actions are often necessary to prevent re-occurrence. Learning from these incidents can often provide potential solutions to preventing safety crises in the future by looking back at what has happened and deriving lessons learned and predicting probable future challenges, (Bond 2002).

'Learning from incidents' (LFI) is a valuable tool in many domains. Much research has been devoted to understanding how this process can be expressed and measured, how worthwhile lessons can be learned through more efficient and effective learning, as proffered by Drupsteen and Guldenmund (2014), Hovden *et al.* (2011) and Jacobsson *et al.* (2011). A main tenet of this reporting system is the ability to report any error or potential error in a 'free and frank' way. This philosophy is intended to be supported by what is termed a just culture, where the outcome for the individual is not based on punitive measures or being inappropriately punished for reporting or co-operating with occurrence investigations. The occurrence reporting system is also intended to be a 'closed-loop' system where feedback is given to the originator and effective actions are implemented within the organization to address the embryonic or evident safety hazards. The concept is progressive in terms of its potential for contribution to identifying and addressing less than optimal performance of human, organizational and technical systems. Understanding that adverse and unwelcome events can be minimized through diligent reporting, event analysis and learning and subsequent necessary intervention is a positive trait with respect to improving acceptable levels of safety.

Argyris and Schön (1996) (pp. 20–21) highlight the importance of learning to detect and address effective responses to errors. Their 'theory in action' concept is the focal point for this determination. The first of its two components, 'theory in use' is one that guides a person's behavior. This is often only expressed in tacit form and is how people behave routinely. Very often these observed habits are unknown to the individual. The second element is known as 'espoused theory', namely what people say or think they do. Drupsteen and Guldenmund (2014) mention that espoused theory comprises of "*the words we use to convey what we do, or what we like others to think we do*".

Enabling this learning channel, ICAO Doc 9859 (ICAO 2013b) defines a template for aviation operators and regulators to support the application of a variety of proactive, predictive and reactive oversight methodologies. In addition to routine monitoring schemes, voluntary and mandatory reporting, post incident follow-up; there are regular safety oversight audits. These audits and inspections often set out to establish if there is a difference between espoused theory and the theory in use, e.g., is the task being correctly performed in accordance with the documented procedure/work instruction or is there a deviation from approved data and practice? However, Drupsteen and Guldenmund (2014) caution auditors not to "*focus too much on the documentation of procedures*" alone. In such cases the audit oversight may be ineffective because of its sole focus on espoused theories of the organization only and not the theory-in-use. They progress to translate this idea of poor focus on theory in action and recommend a solution by suggesting a valid learning component arising from the incidents. They also highlight the 'espoused' aspect where those attempting to learn from incidents often fail to experience the desired learning because outcomes are not fully aligned with the practical objectives of an LFI initiative. For learning to be most effective, espoused theory and theory in use should be reasonably well aligned.

Aircraft maintenance and continuing airworthiness management activities that are performed in European member states are moderated by rules that mandate reporting of defined incidents and occurrences. Repositories of reported data tend to be populated only from sources predominantly aligned with mandatory incident/occurrence reporting requirements. Conventional safety oversight models only verify the presence of reporting media and repositories in this segment of the industry. Traditionally there has been a focus amongst organizations to ensure details of reports are submitted in line with state's mandatory reporting obligations. However, it is possible such a narrow focus on a single element (i.e., reporting alone) of an incident in its lifecycle could negate the potential learning benefits that might accrue from considering other likely related sources. As a result, the absence of clear regulatory requirements capable of augmenting learning from incidents could be considered an impediment to effective learning in the domains affected by EU regulation 1321/2014 (1321/2014). The featured industry sector is regulated by the application and upkeep of numerous requirements in each jurisdictions of operation. In general, oversight duties tend to be carried by regulating states and operators in support of safe and profitable activity. However, a growing tendency to just increase some regulatory requirements across the segments may not always offer the same safety returns necessary for states in the future.

Up until some years ago, basic risk mitigation methods had remained unchanged. The previously reactive initiatives had largely been based on post-event analysis of accidents and incidents. At present, learning from past incidents, occurrences and accidents must be credited with playing a major part in helping evolve the paradigm to the more proactive means of risk management in many aviation segments we know today. Accident models (Heinrich and Reason) can sometimes inadvertently contribute to an over-simplification of how accident and incident contributing factors are perceived. This can result in striving to establish a singular root cause. Understandably the propensity for those tasked with accident and incident investigation is sometimes to establish a linear view based only on apparent causal factors. Proactively identifying precursors to events or potential conditions can greatly assist in averting latent or undiscovered conditions. Since the early 1990s, the potential for organisations to learn from incident precursors and conditions has been worthy of attention. Cooke (2003) endorses a suggestion that increased reporting of incidents enhances continuous improvements in high reliability industries. In the continuing airworthiness segment of the industry, here is often a regulatory driven focus on establishing a single root cause. The importance of adequate resources and efforts to determine accurate incident causation and the measures to prevent reoccurrence should be a primary concern. Until ED 2020/002/R (2020/002/R 2020) is fully implemented, it is possible that the custodians of current regulatory requirements are satisfied once a root cause is established. Could it be that the current popular practice of pursuing (singular) root cause focus can be a lost opportunity when additional related sources exist?

The harvesting of information from incident reporting systems is a necessary input to continuously develop appropriate and effective recurrent training material. The inclusion of basic qualification criteria for human factor trainers in the regulatory requirements should also be addressed. However, it is questionable if the perpetuation of these measures alone would support more effective delivery and application of lessons learned throughout the segment. One means of addressing this impending issue is to remodel regulatory, operational and training requirements to consider a new approach in the segment. Reflecting a combination of actions, events and conditions in a new basic model supporting human factor continuation training, may lay the foundations to better elucidate event causation and yield improved and sustainable safety recommendations in the featured segment.

5.3. A Model Supporting Learning from Incidents

5.3.1 Model Design and Description

Currently European measured levels of aviation safety are generally considered as acceptable. As domain activity is expected to increase in the coming decades, further steps to improve or at least preserve contemporaneous levels of safety will have to continue to be developed. One of the main facets of safety management is the reporting, collection, analysis and to Annex 19 (ICAO 2013a). This is also highlighted in an EU communication COM/2011/0670 (COM/2011/0670 2011) and (EU) 376/2014 (376/2014) . A primary reason for the emphasis on reporting and subsequent learning from incidents (LFI) is to enable and support a shift from prescribed safety oversight to a risk-based programme. This is seen as the best fit to enable and effect improvements in areas that will present the most risk (Cooke and Rohleder 2006). Figure 5.1 presents one view of a generic incident lifecycle (Drupsteen *et al.* 2013) integrated with an interactive framework arising from the researchers work. This 'proposed enhancement' could augment a learning dimension in the cycle of an incident.

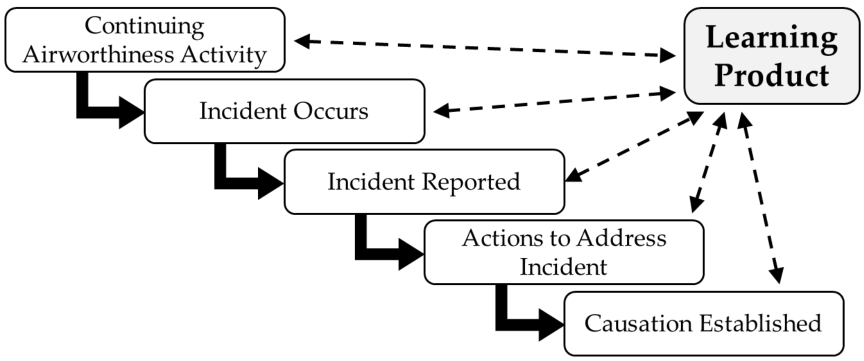

Figure 5.1. Incident learning product and process (Broken line denotes iterative learning feedback).

Figure 5.1 also illustrates a view of the overall process employed to acquire, process and store incident data. The 'broken line' arrows signify an iterative action at each stage of processing the incident. The purpose of this is to ask and record what can be learned at each point? The motif of how a learning product originates from the regulatory perspective is also featured. The effectiveness of the learning from the event is considered in terms of how This is evident from feedback originating from the actions in the cycle when the learning product is being developed. Closing the learning loop is also necessary and reflected in graphic form. In addition to this, assessing actions at each incident stage is intended to support an analysis of how effective resulting actions are in terms of preventing recurrence of the incident. Actions to prevent the recurrence of the same or similar events can be embodied as a result of how effective the learning was. As such the novelty of this framework exists in its clear visual representation rather than the actual arrangement of the specific stages recorded. Traditionally the industry focus on incidents and occurrences has pivoted solely around the reporting requirements. These obligations are the backdrop against which mandatory reporting activity takes place. The establishment of causation is required by regulatory process but little or no suitability of same is mandated by requirement in support of any potential for learning. The featured framework serves to present the main elements of an incident during its lifecycle and highlight the aspects to be considered when incidents are being used in support of developing effective safety lesson delivery.

5.3.2 Model Implementation

The area of focus for this paper is aircraft maintenance and continuing airworthiness management (1321/2014) activities. It was decided to establish contact with an Irish Aviation Authority (IAA) European central repository for aviation accident and incident reports (ECCAIRS) focal point. Following a briefing, a specific permission was granted to review a data set of deidentified mandatory occurrence reports (MOR's) for the purpose of academic analysis. The operational theatre of activity involved licensed air carriers operating large aircraft on the Irish civil aircraft register. The permission allowed an initial physical database search to be performed from June 2019 to November 2019 using 'Part 145 (maintenance) and Part M (continuing airworthiness management)' as the search terms for de-identified report content. Approximately 200 results came back. The narrative and content of each report was reviewed by the researchers for applicability to the analysis. This exercise refined the reports under review to a data set of 85. Figure 5.2 presents an overview of the analysis framework, (IAA) European central repository for aviation accident and incident reports (ECCAIRS) focal point. Following a briefing, a specific permission was granted to review a data set of deidentified mandatory occurrence reports (MOR's) for the purpose of academic analysis. The operational theatre of activity involved licensed air carriers operating large aircraft on the Irish civil aircraft register. The permission allowed an initial physical database search to be performed from June 2019 to November 2019 using 'Part 145 (maintenance) and Part M (continuing airworthiness management)' as the search terms for de-identified report content.

Approximately 200 results came back. The narrative and content of each report was reviewed by the researchers for applicability to the analysis. This exercise refined the reports under review to a data set of 85. Figure 5.2 presents an overview of the analysis framework, described in the sequel.

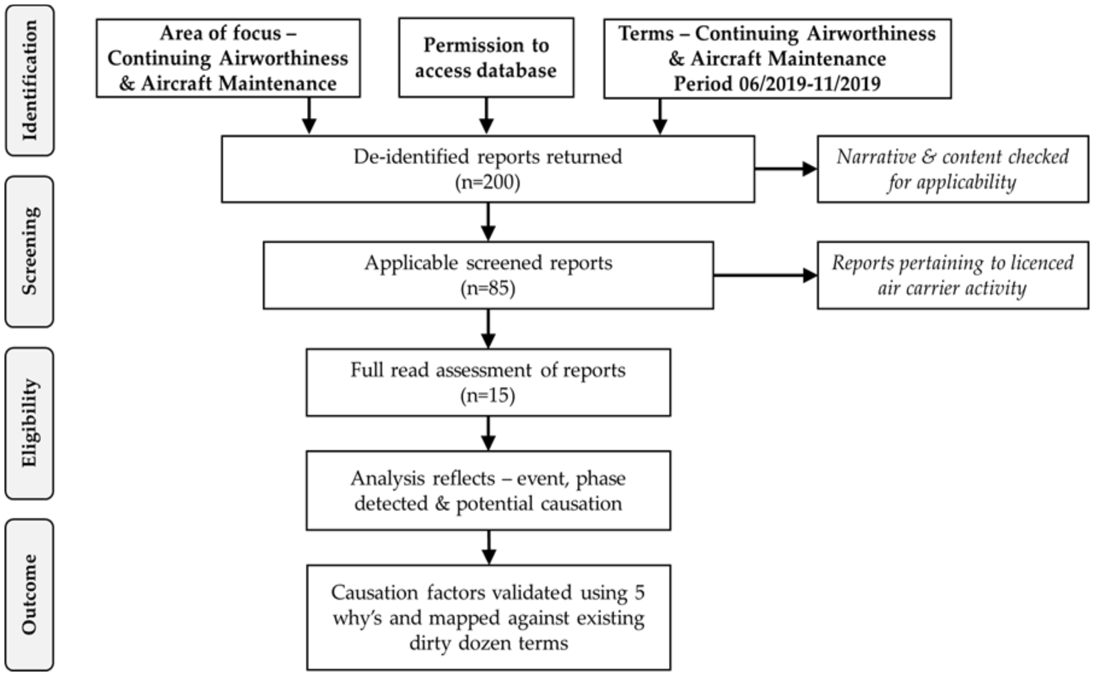

Figure 5.2. Overview of the analysis framework applied. The systematic review phases (identification-screening-eligibility-outcome) follow the methodology of Liberati *et al.* (2009).

5.3.3 Model Validation: Report Causal Elements

A third round of full read screening of the set yielded 15 deidentified reports applicable to the exercise topic. Each featured event was considered under the following elements: the actual event, maintenance phase detected and likely potential causation factors. Table 5.1 contains an overview of this analysis output. Each of the 15 analysed occurrence reports provided a description of the featured event and some were helpfully contextualised with a chronological timeline when included in the report body. This later assisted with appreciating all the potential causation elements for each event. However, the reported verbiage tended to terminate mostly with a focus on consequential impact rather than causal information. For the sake of consistency across the analysis, the authors decided to apply a systematic approach to elicit and validate causal factors from the data. The process was based on a clear definition of root cause as proffered by Paradies and

Busch (1988) as: '*the most basic cause that can be reasonably identified and the management has control to fix'*.

Table 5.1. Results of the analysis of 15 incidents and mapping against the 'Dirty Dozen'.

	Potential causation factors for each analysed incident	**Dirty dozen 'taxonomy'**	
		Primary	**Secondary**
1.	Incorrect tooling Competence for task Task sequencing	Lack of resources Lack of knowledge (Knowledge, skills, ability) Complacency Lack of awareness	Norms established Lack of communication Lack of assertiveness
2.	Continuing airworthiness management organisation (CAMO) management system competence Production pressure	Lack of knowledge (procedures & knowledge, skills, ability) Lack of communication Pressure	Lack of resources Stress Fatigue/Stress/Distraction
3.	Inadequate aircraft maintenance programme (AMP) inspection task Product design	Norms established Lack of communication	Lack of awareness Lack of resources
4.	Inadvertent damage Incorrect gauge of locking wire & locking technique	Distraction Lack of knowledge (Knowledge, skills, ability) Fatigue Lack of teamwork	Complacency Lack of awareness
5.	CAMO work request incorrect Maintenance procedure not followed	Lack of knowledge (Knowledge, skills, ability) Pressure Lack of assertiveness	Norms established Lack of resources
6.	Procedure design Production pressure Competence for task CAMO management system competence	Lack of knowledge Pressure Lack of awareness Lack of communication	Lack of resources Fatigue/Stress/Distraction Lack of supervision
7.	Production pressure Competence for maintenance task	Pressure Lack of knowledge (Knowledge, skills, ability)	Fatigue/Stress/Distraction Lack of resources
8.	Maintenance data availability Production pressure Competence for task	Lack of resources Lack of knowledge Pressure	Norms established Fatigue Lack of awareness
9.	Procedure design Production pressure Supervision Competence for maintenance task	Lack of knowledge (Procedures) Pressure Lack of knowledge (Knowledge, skills, ability)	Lack of awareness Lack of communication Complacency Lack of assertiveness
10.	Incorrect tooling Competence for maintenance task Task sequencing	Lack of knowledge Lack of awareness Lack of communication	Norms Lack of resources
11.	Maintenance data Procedure design Production pressure Competence for maintenance task Post task leak-check	Lack of knowledge (Knowledge, skills, ability) Pressure Lack of awareness	Lack of teamwork Complacency Fatigue/Stress/Distraction Lack of resources
12.	Production pressure Competence for maintenance task Maintenance data availability Supervision	Pressure Lack of knowledge Lack of teamwork	Fatigue/Stress/Distraction Lack of resources
13.	Competence for maintenance task Production pressure	Lack of knowledge Pressure	Fatigue/Stress/Distraction
14.	Culture Risk taking Competence Supervision	Norms established Lack of resources Lack of knowledge (Knowledge, skills, ability)	Lack of awareness Complacency Lack of communication
15.	CAMO procedure competence Culture Supervision	Lack of knowledge (Knowledge, skills, ability) Norms Stress	Lack of awareness Lack of resources Pressure

Many analysis tools [e.g., Fault tree analysis (FTA), functional resonance analysis model (FRAM), systems theoretic accident model and process (STAMP), sequentially timed events plotting (STEP)] are available and can be applied in support of a systematic review aimed at establishing causal factors. However, each of the aforementioned is generally applied in support of more voluminous operational applications and a degree of familiarity and adequate resources are usually required to ensure an efficacious outcome. As the incident reports (n = 15) under review already had causal factors ascribed, the authors deemed a simple analysis tool to be appropriate. According to Card (2017), the '5 Why's technique' is a widely used technique applied in support of root cause analysis and is used by many statutory organisations globally. Ohno (1988) (p. 123) highlights that by repeating why five times, the nature of the problem as well as its solution becomes clear. As the authors of this paper were aware, sole reliance on a tool like the 5 Why's has limitations. In particular, exclusive operational reliance on its prowess as a revealing panacea could inveigle its users in to over-simplifying an event and thereby be seduced into pursuing an inappropriate singular cause. As a result, the tool was applied solely as a mechanism to validate the already operator ascribed event categorisations and causal factors.

5.4 Results

Each mandatory occurrence report (MOR) was thoroughly reviewed, and the content of the event and related actions carefully assessed. However, without an intimate knowledge of the operational environment, history of the aircraft reliability and related operational dynamic and contextual influences for example, it was not possible to definitively establish if the recorded causation and related factors were indisputably accurate for each event. Notwithstanding the foregoing, based on the authors experience and judgement the recorded causation factors were harmonised with a taxonomy derived from the elements of the Transport Canada (2003) 'dirty dozen' terms associated with common error preconditions. The elements are generally identified as, Lack of communication, Distraction, Lack of resources, Stress, Complacency, Lack of teamwork, Pressure, Lack of awareness, Lack of knowledge, Fatigue, Lack of assertiveness, Norms. The purpose of aligning the 'potential incident causation factors' with a known taxonomy is to assist with developing clear learning product content and learning objectives. Regulatory code or guidelines for the continuing airworthiness domain do not require a formal approach to learning such as those defined by Bloom (1956) and Anderson and Sosniak (1994). Although the reports featured display similar activity profiles, recognition for the need to consider learning taxonomies and the importance of domains of learning (cognitive, affective and psychomotor) when designing continuation training programmes is considered essential. In addition, organisations are not required to have a formal mechanism of assessing efficacy, instead many take comfort in national, European and international holistic safety reports as a means of gauging their performance as part of the collective.

Assuming the purpose of learning objectives is to assist with the delivery and measurement of the effectiveness of learning actions, developing an overview of a harmonised taxonomy is helpful in this regard. In Table 5.1 above, potential causation factors for each of the 15 selected incidents were matched with the twelve elements of the 'Dirty Dozen' human factor taxonomy. In order to prevent an over-simplification of each event's contributing factors, the authors were careful not to be seduced into seeking a singular root cause. Therefore, it was decided to include both primary and secondary human factor elements so that causation could be considered in a holistic manner. The following paragraphs (a–h) and Figure 5.3 give a breakdown of the issues emerging from the assessment of the mandatory occurrence reports (MOR's) as seen through the lens of association with a taxonomy.

- **a.** Lack of knowledge features as a primary element in 13 (87%) of 15 occurrences. This can be closely related to the competence required to perform the task as it relates to aircraft maintenance and continuing airworthiness management activities which are defined as comprising of 'knowledge, skills and attitude/ability' (1321/2014). As a secondary potential contributing element, it relates to only 1 (7%) of the 15 occurrences.
- **b.** Lack of awareness is highlighted as a primary potential causation factor in 9 (60%) of the 15 reviewed occurrences. This element can be closely related to competence, communication and teamwork. As a secondary contributing factor, lack of awareness was noted during the review in 5 (33%) of 15 reviewed occurrences.
- **c.** Lack of resources were recorded in 3 (20%) of 15 events. Adequate resources are required in order for an operator to adequately staff an organisation so that an aircraft can be maintained to the correct standard and when required. EU 1321/2014 (1321/2014) mandates that a manpower plan is maintained in support

of ensuring adequate levels of staff are consistently available. As a secondary issue, lack of resources appeared as an issue in 5 (33%) of 15 cases. Ultimately, accountable managers are the key to ensuring sufficient resources are made available so that the organisational elements continue to remain compliant and effective in this respect.

d. Norms accounted for 3 (20%) of 15 reports examined. Norms are often viewed as behaviours that are developed and accepted within a group. However, when the resulting behaviour requires a deviation from approved procedural function, the consequences are often unknown. Although such actions may offer short-term productivity gains, they may also introduce active and latent safety hazards. In the case of secondary causation, norms are associated with 8 (53%) of 15 assessed occurrences.

e. Lack of communication was found to be evident in 3 (20%) of 15 occurrences in the study. Communication in aircraft maintenance and management activities is a vital element in the release of a safe product. Poor communication can amplify many other elements of the human factors leading to a deterioration in human performance, (Chatzi 2019), (Chatzi *et al.* 2019). 2 (13%) of the 15 reviewed communication-related occurrences were recorded as contributing to secondary event causation.

f. Complacency was revealed as a primary factor in the causation of 1 (7%) of 15 events studied. However, as a secondary contributing factor it accounted for 5 (33%) of 15 reports. Stress levels associated with a task can diminish performance if one becomes complacent. Its presence can contribute in concert with other elements capable of setting the scene for an unwelcome event.

g. Stress as a primary factor appeared in 1 (7%) of the 15 reviewed events. However, it was associated with 2 (13%) of 15 reports as a secondary issue. Stress can be both a by-product and an enabler of other Dirty Dozen elements. Fatigue for example can be closely coupled to stress and displayed similar pattern in the study with 7% and 13% respectively of prevalence in the reports reviewed.

h. Lack of assertiveness was evident as a primary and as a secondary causation factor in both cases and occurring at rate of 1 (7%) of 15 events under review. Distraction and lack of teamwork appeared in similar proportions in the review results.

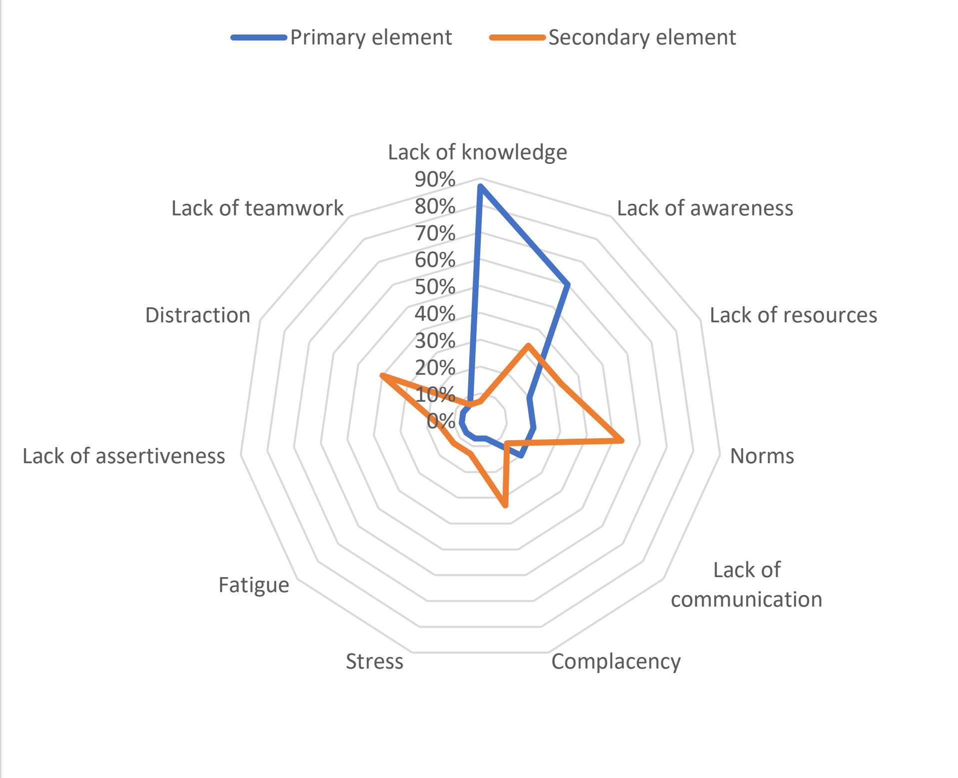

Figure 5.3. Representation of primary and secondary causation in the reviewed occurrence reports.

5.5 Discussion

Recalling the causal factors attributed to the featured occurrence reports in the paragraphs above, it is easy to appreciate their relationships with the 'Dirty Dozen' example of human factor elements. For example, lack of resources can be a major constraint when it comes to providing adequate levels of appropriately qualified competent staff. Pressures exerted upon staff in a dynamic industry sector to absorb additional workload can of course have a potentially detrimental effect on safe operations. Competent and available supervision of maintenance and inspection staff is a core requirement of a quality mission in aircraft maintenance and continuing airworthiness management operations. In many regions the maintenance requirements [e.g., EU regulation 1321/2014 (1321/2014)] stipulate a process whereby all staff must meet the qualification criteria and be deemed competent before unaccompanied work can take place. For the purpose of the discussion, key elements of the incident cycle components are examined through pertinent elements identified during the analysis. The iterative approach suggested during the management of the incident information is supported by the context outlined below. Understanding the relevance of each of the sections is intended to support more effective learning outcomes.

The following paragraphs discuss the incident cycle from the perspective of developing a sound learning product.

5.5.1. Acquiring, Processing and Storing Incident Data

According to Garvin (1993), a clear definition of learning has proven to be elusive over the years. Garvin suggests "*a learning organization is an organization skilled at creating, acquiring and transferring knowledge and at modifying its behaviour to reflect new knowledge and insights*". Figure 5.1 illustrates the evolution of an incident as it is managed through its cycle. The incident/occurrence will need to be detected if it is to possess any potential for learning. Acquiring information in support of learning is one of the key actions. Such learning material originates from compliance audits, amended regulatory requirements, best practice, and incidents and occurrence reports. Within the greater area of aircraft maintenance and continuing airworthiness management, details of incidents and occurrences tend to be reported soon after an event. Reporting requirements are normally timebound (i.e., 72 h). Most organisations endeavour to notify the necessary stakeholders as soon as possible, often by telephone in the first instance. As many airline staff are employed on a shift work basis, the window of 72 h is useful in support of administering the reporting function. It is not unusual to have numerous points of contact for reporting within organisations. However, reporting generally follows a consistent route regardless of who the initial point of contact is. Some organisations appear to empower and encourage the submission of reports by any individual. Other organisations appear to endorse reporting through a 'chain of command'. Regardless of the chosen initial reporting route input, all reports are progressed to a 'gate-keeper' within an organisation. The people responsible initially for examining the validity and completeness of submitted reports often hold a key position in either the quality assurance, technical services or maintenance departments. Generally, there is a strong awareness of the need to report incidents and occurrences classified as mandatory. There may be numerous motivational reasons to report, such as ethical, safety, compliance with regulatory requirements and best practice for example. Those submitting reports embrace mandatory reporting as an obligation underpinned by the cultural norms of aircraft maintenance and continuing airworthiness management. When an issue is discovered, it is progressed through the reporting system regardless of its status. Many organisations welcome all reports including non-mandatory events that are highlighted through voluntary reporting streams. They evidently see value in including them in their analysis of events and the subsequent learning opportunities the reports may offer.

5.5.2. Single, Double and Triple-Loop Learning

From an organisational point of view, single-loop learning can be experienced when an error is detected and corrected but little else changes, Argyris and Schön (1996) (p. 18). In aircraft line maintenance environments where a 'find and fix' ethos prevails, single-loop learning is often evident. It is not unusual for technical issues to befall an aircraft's departure time. Such pressure points often associated with fulfilling contractual obligations may have a negative impact on the potential for learning from a related event. In such cases, if issue arises the matter may be resolved without any further recorded action. Because of the terse nature of the experience for an individual concerned, the opportunity for further learning may not extended beyond the single loop. Argyris and Schön (1996) (p. 21) and Lukic *et al.* (2012) proffer double-loop learning as learning that takes place and results in organisational norms and theory in use being altered. Presently, aircraft certifying, and support staff are obliged to continuously preserve an adequate understanding of the aircraft being maintained and managed along with associated regulations and procedures. A desired outcome of double-loop learning is often witnessed for example through the adjustment of environmental, behavioural and procedural norms. Instances of double-loop learning can be evident following unsuccessful attempts through single-loop learning. In-service continuation training is an effective enabler that is capable of supporting double-loop learning. Organisations are also required by EU 1321/2014 (1321/2014) to establish and maintain a continuation training programme for staff. A primary pillar of continuation training syllabi is the use of incidents and occurrences as lesson content for influencing organisational norms and behaviour in support of preventing recurrence of incidents and occurrences. Deutero-learning (triple-loop) relates to when members of an organisation reflect upon previous learning and sets about to improve how the organisation can refine and improve the process of learning from events, (Argyris and Schön 1996) (p. 29), (Bateson 1972). This could also be stated as learning how to learn by seeking to improve single and double loop learning. Although deutero-learning may be considered as a natural extension of other levels of learning, the concept does not feature as a requirement in aircraft maintenance and continuing airworthiness management regulatory codes.

5.5.3. Learning Product

Aircraft maintenance and management regulatory codes require reporting of "*any identified condition of the aircraft or component that has resulted or may result in an unsafe condition that hazards seriously the flight safety*" (1321/2014). Generally, a learning product can originate from numerous information sources within the aircraft maintenance and continuing airworthiness management arena. Specifically, GM1 145.A.30(e) (1321/2014) requires the use of accident and incident reports in support of the mandatory human factors training content. The intent of this material is to ensure information is imparted upon the organisations' staff in support of preventing the subject event reoccurrence. Such continuation training is mandated by European requirements for all aircraft maintenance and continuing airworthiness management organisations. Continuation training is also a product as well as a medium for imparting learning from incidents. Inputs to continuation training syllabi often feature learning from incidents and experience augmented by safety notices, toolbox talks and are recognised as a means of presenting the learning product to operational staff. Drupsteen and Guldenmund (2014) cite, Lampel *et al.* (2009) where they use the term "*learning about events*". This is further explained as "*information about events is shared and diffused to help create new ideas*", in this case in the support of safe operations.

5.5.4 Effectiveness of Learning

The evaluation of any initiative's success is much more straight forward when clear objective indicators (learning outcomes) are employed. In the case of learning in an aircraft maintenance and management environment, organisations can generally employ indicators such as inspection non-compliance, audit findings and rates of incident reoccurrence in support of gauging the effectiveness of learning. Probing salient aspects such as timely investigation of incidents, assessing the learning content and feedback are a starting point for assessing effectiveness. Cooke (2003) concludes the absence of or poor information can compromise the effectiveness of feedback. He also suggests that if the feedback cycle is ailing, the climate may deteriorate and have a negative impact upon organisational safety. From a commercial viewpoint, it is perhaps understandable that aircraft tend to only generate revenue when flying. However, airline operators need to maintain a balance between safe operations and productivity. It is essential that incident causal factors are fully identified and adequate time and resources are available to support this important aspect of learning. Cooke (2003) endorses a suggestion that increased reporting of incidents enhances continuous improvement in high reliability industries. However, establishing adequate causation is also an attribute capable of supporting effective learning from an event in dynamic environments.

The importance also of just culture as an enabler for incident reporting and subsequent effective learning cannot be ignored. Under-reporting of events resulting from a single-loop learning experiences amongst operational maintenance staff and production pressures can also impact negatively upon efforts to propagate a learning environment. McDonald *et al.* (2000) suggest from their analysis, 'that there is a strong professional sub-culture, which is relatively independent of the organization. One implication of this finding is that this professional subculture mediates the effect of the organizational safety system on normal operational practice'. von Thaden and Gibbons (2008), conclude safety culture "*refers to the extent to which individuals and groups will commit to personal responsibility for safety; act to preserve, enhance and communicate safety information; strive to actively learn, adapt and modify (both individual and organizational) behaviour based on lessons learned from mistakes* . . . .". A just culture is defined in the affecting regulation EU 376/2014 (376/2014) as, "*a culture in which front line operators or other persons are not punished for actions, omissions, or decisions taken by them, that are commensurate with their experience and training, but in which gross negligence, wilful violations and destructive acts are not tolerated*". Accordingly, a just culture is a fair culture. The effectiveness of the learning system can also be compromised by its efficiency as well as its inadequacies. The volume of information that staff must process and assimilate is continually increasing. Guardians of learning outcomes should be mindful that staff risk becoming information weary as a result of the ever-increasing demands on their cognitive abilities.

5.5.5 Types of Knowledge

This relates to; conceptual, dispositional, procedural and locative knowledge forms (Thorndike 1918). One of the key objectives of learning from incidents is to identify the type of knowledge needed to prevent an issue recurring. When a reportable issue for example is discovered, the submitted report will identify 'what' happened. Subsequent follow-up will set out to determine 'why' the issue occurred. The guiding principles of 'how' to perform the task or operation are often contained in procedures or data particular to the task. The information contained in procedures will enable a person to utilise other forms of knowledge. Prevailing culture within an organisation will have an impact on learning from incidents. If a strong commercial culture exists, this may have an impact on for example the depth and breadth of learning from incidents within the company. Induction and initial training for new staff is an important element for demonstrating where organisational sources of information can be accessed. Accident data repositories contain many well documented examples of human factor related precursors to incidents. Many of which may have originated in poor access to approved data and culminated in serious and possibly preventable incidents. Acknowledging and addressing the limitations related to the types of knowledge when developing continuation training programmes would have a positive impact on participants. The enabling industry requirements do not specify any discernible differences in how the types of knowledge are differentiated. A review of the human factors syllabus requirements did not highlight a need to appreciate or account for these human centred limitations when designing and delivering training lessons.

5.6. Conclusions

It has been highlighted during this research that the opportunity to learn from incidents is not being fully embraced in the aircraft maintenance and continuing airworthiness management segment of the industry. While the idea of eliminating all incidents is a fallacy, reducing their numbers and potential for harm is a reality. Air travel is on the increase and it is envisaged that current sectors flown will have doubled within the next two decades. If current levels of safety were to remain stagnant with a doubling in activity, twice the current fatality rate would surely not be acceptable. Many people relate safety to freedom from risk and danger (Reason 1997). Unfortunately, risk and danger are often ubiquitous in the presence of aircraft maintenance and continuing airworthiness management activities. Managing sources of risk and danger is a tall order for some organisations. Document 9859 (ICAO 2013b) recognises that "*aviation systems cannot be completely free of hazards and associated risk*". However, the guidance does acknowledge that as long as the appropriate measures are in place to control these risks, a satisfactory balance between 'production and protection' can be achieved. Perrow (1999) (p. 356) acknowledges that "*we load our complex systems with safety devices in the form of buffers, redundancies, circuit breakers, alarms, bells, and whistles' because no system is perfect*".

Detecting and identifying hazards highlighted through incident reporting systems is recommended by ICAO standards and recommended practices as an effective means of achieving practicable levels of safe operations. Therefore, objective data mined from a reporting system offers the potential to enlighten aviation stakeholders and to illuminate weakness that may be present. Such information can assist with a better understanding of events and augment mitigating measures against the potential effects of these hazards. When incidents occur, this can be an indication of a failure in an organisation's process and/or practice. Because of continuous challenges faced by organisations in the aviation industry, there is still potential to learn from resulting incidents and pre-cursors. The learning is based on the potential new knowledge available from the associated collection, analysis and interventions for these events. Effective learning can be considered as a successful translation of safety information into knowledge that actively improves the operating environment and helps prevent recurrence of unwelcome events.

The paper features a brief exercise to demonstrate how safety information can be translated into lessons capable of augmenting knowledge within an aircraft maintenance and management organisation. To support this, fifteen occurrences drawn from an ECCAIRS incident database portal were analysed. The result of the analysis along with potential causation factors are presented. Additionally, a simple mechanism in support of the delivery of associated safety lessons was developed and is presented in Table 6.1 above. Integrating the known causal factors with the 'Dirty Dozen' taxonomy which is already associated with this aviation segment provides a useful template for continuation training in the segment. The emerging incident/occurrence themes related to the featured events are briefly discussed and presented within the document. The publication also introduces a framework that assembles and explains the main elements of an incident within its lifecycle. The purpose of this is to illustrate tacit aspects of an incident that have the potential to augment learning within the process. In order to leverage the maximum benefit from details of an incident, learning processes must recognise the existence of these event components. There can therefore be a formal approach to gauging the effectiveness of learning and a means of identifying underperforming elements of the learning process. This publication could assist subject organisations with a review of their management of incident information when developing continuation training material and learning outcomes.

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Conflicts of Interest: The authors declare no conflict of interest.

Applicability of results

The authors consider the validity of the findings to extend outside of the Irish State and are applicable to other European member States. The consistent and robust application of EASA requirements throughout Europe underpins a standardized application of this across a pan-European continuum.

Concluding statement

The following Conclusions chapter will outline the research outputs and how the objectives were met. The utility value of the work and opportunities for future research will be considered.

Chapter 6. Conclusion

The research has highlighted that the opportunity to learn from incidents is not being fully embraced in the aircraft maintenance and management segment of the industry. While the idea of eliminating all incidents is a fallacy, reducing the number of events and the potential for harm is a reality. Structured and continuous safety management actions, such as collection of data, analysis and intervention can be enabled with the support of the necessary safety intelligence. Air travel is on the increase and it is envisaged that current sectors flown will have doubled within the next two decades. If present levels of safety were to remain stagnant with a doubling in activity, twice the current fatality rate would surely not be acceptable. However, because of continuous challenges faced by organisations in the aviation industry, there is still potential to learn from resulting incidents and pre-cursors.

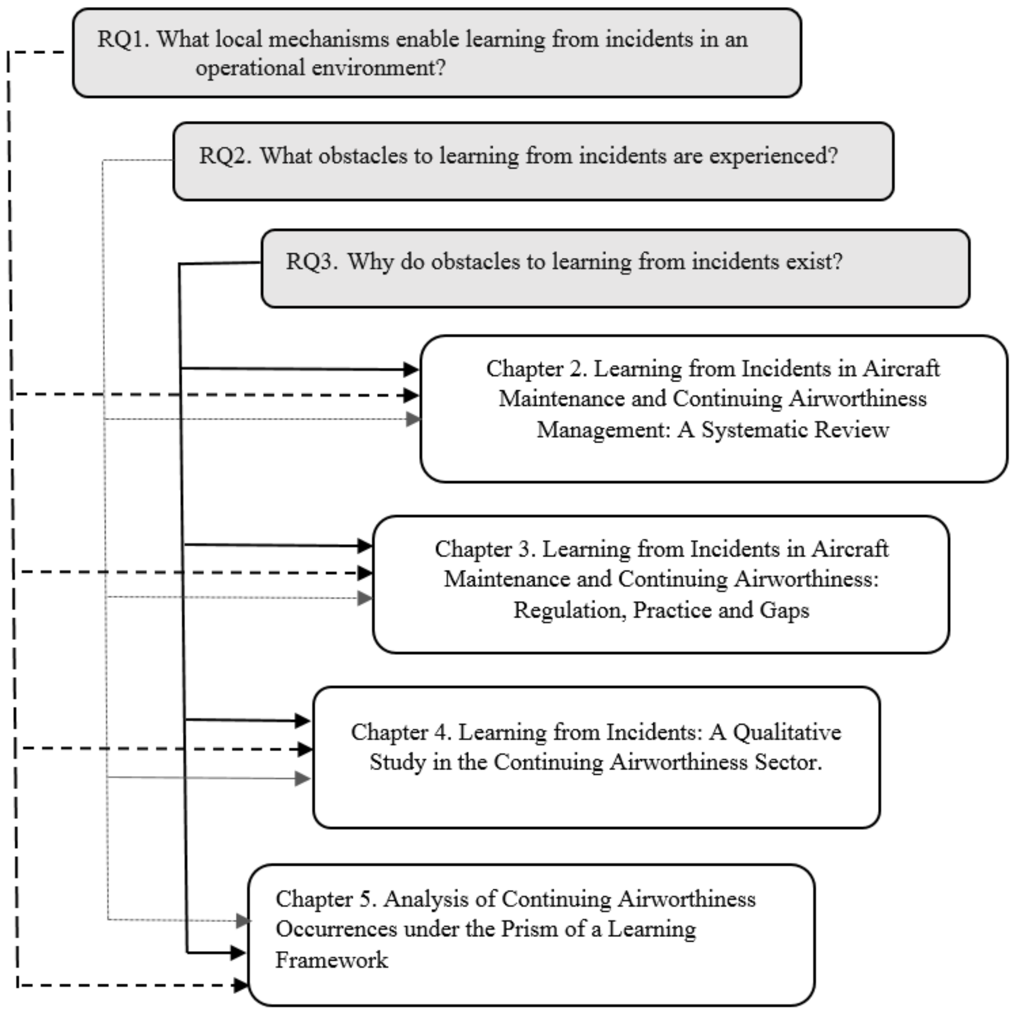

Figure 6.1. Architecture of papers and contribution to research questions.

The study's over-arching research questions are again shown in figure 6.1. Chapter 2 considers the current body of literature that supports learning from incidents and addresses all three research questions. The outputs from this chapter reveal how learning takes place within a specified set of organisations and brings forward enablers and constraints to learning from incidents.

Chapter 3 examines the statutory requirements for the aircraft maintenance and continuing airworthiness management segment. The prescribed mechanisms and their constraints are identified and directly address all three research questions.

Chapter 4 documents the current situation in respect of learning from incidents within the subject domain. The analysis of the data uncovered how staff learn from incidents and which enabling and constraining factors exist within the organisations under focus.

Chapter 5 presents an innovative approach to improving LFI through the identification of learning constraints presented in the earlier papers. The augmentations are centred around an improvement in focus on the learning product withing the learning cycle.

As evidenced by the research, many contributing factors impinge on the effectiveness of learning initiatives. A concomitant way to augment the segment's regulatory oversight would be to expedite the transition to a risk-based methodology. An effective input to oversight is the output from lessons learned, where potential risks can be adequately addressed, and proportional mitigating effort brought to bear where necessary. While the EU requirements for aircraft maintenance and management currently define a high-level syllabus for human factors training content, it does not provide guidance on lesson content, consider organisational behaviour or suggest basic qualification and competence requirements for instructors.

Following the analysis of data specifically collected for this project and related literature, the main conclusions can be summarised as follows:

- Under-reporting of incidents can be due to cultural norms established amongst maintenance crews and/or production pressures.
- Establishing root cause and ancillary factors related to an incident are not always adequately resourced. Therefore, potential available lessons are not always highlighted and translated in lessons learned.
- No formal qualification or competence requirements exist for staff responsible for developing and delivering mandatory human factors (HF) training that comprises of lessons learned content.

- Just culture has a positive impact upon incident reporting rates.

Failure to formally reflect fundamental principles of learning in the implementing requirements will continue to detract from the effectiveness of initial and continuation training initiatives. Often, due to perceived cost considerations, organisations tend to only expend sufficient effort to meet minimum compliance requirements. Therefore, the EU directive concerned should be amended without delay to include effective guidance in support of augmenting its capability in terms of risk-based oversight initiatives. The study results could be used to develop terms of reference to establish a European Aviation Safety Agency (EASA) working group capable of updating rule-making requirements in the area of focus. The research could also be applied to the analyses of incidents and further employed in support of examining organisational use and productivity of incident learning data.

In addition to addressing the research objectives, this collective body of work makes a significant contribution at the level of the individual stakeholder, the organisation and those with domain regulatory oversight obligations. The work illuminates a pressing need to broach the matter within the area under focus. The relationships between the expectation to effectively learn from incidents and what is inferred in mandated procedural form is not well appointed in the segment requirements. This inherent deficiency may be a causal factor that has propagated a paradigm that undervalues the capability learning from incidents continues to present. Moreover, it may also share responsibility for the light-touch approach underpinning the regulatory edifice. Acknowledging the findings that arise could influence and augment improvements in competence & causation requirements and further inform a model that articulates a useful learning product centric archetype.

The aim of the research has been to uncover enablers & impediments to learning from incidents and to put forward the utility value of this research. To this end, the research adopted an interpretative/exploratory stance supported by a multi-method research design strategy. The work brings into focus some primary underlying reasons underpinning the under-performance and under-recognised benefits of fully embracing the credo of learning from incidents. The contribution this thesis makes to the body of knowledge is abridged in the following short paragraphs.

The literature re-affirmed the existence of a solid infrastructure capable of supporting the delivery of effective lessons within the area of research focus. Continuing airworthiness as an operational subset is both enabled and impeded by the implementing requirements. This empirical research discloses the further potential impairment associated with maintaining inadequate causation practices and a poor or absent just culture. Existing systematic literature reviews in this area are scarce and this research provides a basis to progressively examine the efficacy of current organisational approaches to learning.

The work also features learning through the lens of the subject activity's enabling and modulating prerequisites. A set of pertinent regulatory standards and recommended practices are reviewed within the context of learning from incidents within the specific area of continuing airworthiness. This review culminated in a contextualist view where the emerging effects of light-touch regulation, absence of specific minimum competence requirements for key knowledge transfer staff, the need to fully appreciate the impact of safety culture and the absence of causation guidelines are made obvious by their omission from regulatory tomes. The research outputs are valid inputs for those tasked with the development of regulation and best practice, not only in the aviation sector but also parallel high-reliability domains. With the projected increases in air movement in the coming years and the need to reciprocate with progressive oversight methodologies, this independent research is a valuable digest.

The encompassing qualitative study offers an insight into how lessons are actually delivered within the participating organisations. It also considers the inherent infrastructural challenges that exist as a backdrop to this activity. The study offers a deep insight into the evolution of the data gathering instrument and features the rich benefits accrued from the related focus group activity whilst also recounting the influence the outputs from the literature review had on the instrument's development. The application and documentation of a thematic analysis within the area of learning from incidents is considered a novel approach that capably captures the themes that emerged from the data sets. Evidence of multi-domain impediments shared by the subject segment are set forth in the systematic literature review's a priori domain epitomes which are considered at an applied level. Echoes of inadequate causation and poorly designed incident learning syllabi to name some of the encumbrances, clearly resonate within the results. The emerging salience of the research outputs could serve as a baseline for affected stakeholders wishing to gauge performance of existing oversight systems or those solely pursuing a means of introducing improvements.

The application of the LFI principles to an incident subset illustrates one means of translating safety data into tangible lessons from incidents. This approach is a clear and unambiguous means of highlighting the learning potential incidents can present. The intention is to provide a simple exemplar capable of providing a consistent input to mandatory recurrent training syllabi. Additionally, the learning product centric view of an incident in its lifecycle amplifies the importance of learning from incidents to all stakeholders committed to preventing event reoccurrence.

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Appendix A - Signed Statement of Author Contribution

The four articles listed underneath that comprise this thesis reflect the following author contributions:

Conceptualization, J.C. and K.I.K.; methodology, J.C.; formal analysis, J.C.; investigation, J.C.; validation, J.C and K.I.K.; data curation, J.C.; writing—original draft preparation, J.C. and K.I.K.; writing—review and editing, J.C. and K.I.K. All authors have read and agreed to the published version of the manuscripts.

Clare, J. and Kourousis, K.I., Learning from Incidents in Aircraft Maintenance and Continuing Airworthiness: Regulation, Practice and Gaps. Aircraft Engineering and Aerospace Technology 2021, Vol. 93 No. 2, pp. 338-346.
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Clare, J. and Kourousis. K.I., Learning from Incidents in Aircraft Maintenance and Continuing Airworthiness Management: A Systematic Review. Journal of Advanced Transportation, Vol 2021, pp.1-13.
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